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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
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Intellectual Property Rights

Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Introduction

The present document is a guiding document for the ITS Release 2 set of standards. It provides the main functional needs and system expected context for the realization of Release 2 and beyond ITS services. The present document is part of a set of the ITS Release 2 leading document.

The present document is a new version to trigger first ITS Release 2 standards development and may be further updated till a final version is released which identifies the complete base set of ITS applications supported by the ITS Release 2 and beyond set of standards.

In this case final means the set which is the reference for ITS Release 2 and beyond interoperable equipment realisation.

The present document includes the base ITS Release 2 ITS Services, ITS Applications, and ITS use cases, including their high level functional and system needs relevant for the realisation of the ITS Release 2 and beyond standards interoperability.

1 Scope

The present document identifies ITS services, supporting ITS applications functional and system needs, as well as related use cases which are intended to be the baseline for the development of the set of ITS Release 2 and beyond standards.

The identified ITS services and use cases do not constitute an exhaustive list and new ones could be included in a new version of the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] SAE J3016 (2021): "Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles".

[i.2] SAE J3216: "Taxonomy and Definitions for terms related to Cooperative Driving Automation for On-Road Motor vehicles".

[i.3] CAR 2 CAR Communication Consortium: "Guidance for day 2 and beyond roadmap".

[i.4] ETSI TR 103 832: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Study on ITS Support for Pre-Crash based Applications; Release 2".

[i.5] ETSI TS 122 268: "Digital Cellular telecommunications system (phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); Public Warning System (PWS) requirements (3GPP TS 22.268 version 16.4.0 Release 16)".

[i.6] ETSI TS 103 831: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Decentralized Environmental Notification Service; Release 2".

[i.7] ETSI TS 101 556-1: "Intelligent Transport Systems (ITS); Infrastructure to Vehicle Communication; Electric Vehicle Charging Spot Notification Specification".

[i.8] ETSI TR 103 582: "EMTEL; Study of use cases and communications involving IoT devices in provision of emergency situations".

[i.9] EU EIP (European ITS Platform): "Reference Handbook for harmonized ITS Core Service Development in Europe".

[i.10] TR 17828:2022: "Road Infrastructure-Automated vehicle interactions-Reference Framework Release 1", (produced by CEN).

[i.11] ISO/TS 19091:2019: "Intelligent transport systems - Cooperative ITS - Using V2I and V2V communications for applications related to signalized intersections".

[i.12] ETSI TR 103 578: "Intelligent Transport Systems (ITS); Vehicular Communications; Manoeuvre Coordination Service (MCS); Pre-standardisation study; Release 2".

[i.13] ETSI TR 103 300-1: "Intelligent Transport Systems (ITS); Vulnerable Road Users (VRU) awareness; Part 1: Use cases definition; Release 2".

[i.14] ETSI TS 103 300-2: "Intelligent Transport Systems (ITS) ; Vulnerable Road Users (VRU) awareness; Part 2 : Functional Architecture and Requirements definition ; Release 2".

[i.15] ETSI TS 103 300-3: "Intelligent Transport Systems (ITS) ; Vulnerable Road Users (VRU) awareness ; Part 3 : Specification of VRU awareness basic service ; Release 2".

[i.16] ISO 23374-1: "Intelligent transport systems - Automated valet parking systems (AVPS) - Part 1: System framework, requirements for automated driving and for communications interface".

[i.17] ISO 11783-10: "Tractors and machinery for agriculture and forestry Serial control and communication data network".

[i.18] ETSI TS 102 182: "Emergency Communications (EMTEL); Requirements for communications from authorities / organizations to individuals, groups or the general public during emergencies".

[i.19] Daniel Câmara, Christian Bonnet, Michelle Wetterwald, Navid Nikaein: "Multicast and virtual roadside units for multi technology alert messages dissemination", WMAPS 2011, 1st International Workshop on Mobile Ad-Hoc Networks for Public Safety Systems, October 21, 2011, Valencia, Spain.

3 Definition of terms, symbols, and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

basic set of applications: set of ITS applications which identify all functional and system requirements enabling the development of all interoperability specifications to realize these applications

ETSI Release 2 cooperative vehicle and RSE: vehicle and roadside equipment which conforms to the set of ETSI TC ITS standards published for the support of partly and fully automated vehicles and identified as the "release 2" set of standards

fully automated vehicle: cooperative vehicle of level 4 to 5 which do not require the presence of a human diver in it

NOTE: A central supervisor needs to monitor the progression of such vehicle and be capable to act remotely (teleoperation) on it if necessary.

implementation scenario: sequence of actions controlled by an ITS application to achieve a given goal relatively to an identified use case

ITS application: association of two or more complementary ITS-S applications (a stationary vehicle warning application composed of a transmitting and receiving stationary vehicle warning ITS-S applications)

ITS service: service provided by an ITS application to the user of ITS (e.g. road hazard signalling is an ITS service that can be provided by a stationary vehicle warning application, as well as by many other applications of the same category: slow moving vehicle, weather condition warning, etc.)

ITS Station (ITS-S): functional entity specified by the ITS-Station (ITS-S) reference architecture (e.g. vehicle ITS-S, roadside ITS-S, central ITS-S, personal ITS-S)

ITS-S application: fragment of an ITS application available at an ITS Station that uses ITS-S service to connect to one or more other fragments of the same ITS application (e.g. a stationary vehicle warning application running at a vehicle ITS-S detecting the stationary state and transmitting a notification using the DEN service)

ITS-S service: communication functionality offered by an ITS-S to an ITS-S application (e.g. Cooperative Awareness Service, Decentralized Environmental Notification Service, etc.)

partly automated vehicle: cooperative vehicle of level 1 to 3 which requires a human presence in it

NOTE: Such vehicle may move in an automated driving mode according to its ADASs equipment and the road infrastructure operational capabilities. However, when required, the human driver may be instructed to take back the control of a vehicle moving in an automated mode.

relevant vehicle: cooperative vehicle which is locally impacted during the execution of an ITS service supported by a given ITS application

subject vehicle: cooperative vehicle which executes an action to achieve an ITS service

target vehicle: cooperative vehicle which needs to actively participate in the accommodation of one or several subject vehicle(s) action to reach a particular goal

use case: specific mobility situation which benefits from the efficient support of an ITS application to provide an ITS service to ITS users

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

5GAA	5G Automotive Association
ABS	Anti-lock Braking System
AC-ACC	Advanced Cooperative ACC
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
ADS	Automated Driving System
AEBS	Automated Emergency Brake System
A-GLOSA	Automated GLOSA
AI	Artificial Intelligence
AICW	Advanced Intersection Collision Warning
ALK	Active Lane Keeping
ASVW	Advanced Slow Vehicle Warning
AVP	Automated Valet Parking
C2C-CC	Car to Car Communication Consortium
C2V	Centre to Vehicle
CA	Cooperative Awareness
C-ACC	Cooperative Adaptive Cruise Control
C-AEBS	Cooperative AEBS
C-ALK	Cooperative ALK
CAM	Cooperative Awareness Message
CAS	Cooperative Awareness Service
CCAM	Cooperative Connected and Automated Mobility
CDA	Cooperative Driving Automation
C-ISA	Cooperative-ISA
C-ITS	Cooperative-ITS
CLC	Cooperative Lane Change
CLM	Cooperative Lane Merging
CMC	Connected Motorcycle Consortium
CPM	Collective Perception Message
CPS	Collective Perception Service
CSL	Contextual Speed Limit
DATEX	DATa EXchange
DDT	Dynamic Driving Task

DENM	Decentralized Environmental Notification Message
DENS	Decentralized Environmental Notification Service
DRM	Discovery Request Message
eCall	emergency Call
ERS	Electric Road Systems
ESP	Electronic Stability Program
EU	European Union
EV	Electrical Vehicle
EVCS NM	EVCS Notification Message
EVCS	Electric Vehicle Charging Spot
GLOSA	Green Light Optimal Speed Advisory
GNSS	Global Navigation Satellite System
I2V	Infrastructure to Vehicle
ICT	Information and Communication Technology
ID	IDentifier
IoT	Internet of Things
IP	Internet Protocol
ISAD	Infrastructure Support levels for Automated Driving
ITS	Intelligent Transport System
ITS-S	ITS Station
IVI	In Vehicle Information
IVIM	IVI Message
LAN	Local Area Network
LEMA	Local Emergency Management Authority
MAPEM	MAP Extended Message

NOTE: See ISO/TS 19091:2019 [i.11].

MAPS	MAP Service
MC	Manoeuvre Coordination
MCM	Manoeuvre Coordination Message
MCS	Manoeuvre Coordination Service
MRM	Minimum Risk Manoeuvre
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
P2P	Point to Point
PA	Parking Availability
PAS	Parking Availability Service
POI	Point Of Interest
POIM	Point Of Interest Message
POIM-PA	POIM-Parking Availability
POIS	Point Of Interest Service
POS	POSition
PTW	Powered Two Wheelers
PWS	Public Warning System
RF	Radio Frequency
R-ITS	Roadside ITS
RLC	Railway Level Crossing
RSE	RoadSide Equipment
RSU	RoadSide Unit
RWW	Road Work Warning
SAE	Society of Automotive Engineers
SDO	Standardization Organization (standards developing organization)
SMS	Small Message Service
SNM	Service Notification Message
SPAT	Signal Phase and Timing
SPATEM	SPAT Extended Message
SPATM	Signal Phase And Timing Message
SPATS	Signal Phase And Timing Service
STF	Specialist Task Force
STL	Subject Traffic Light
SV	Subject Vehicle

SVW	Slow Vehicle Warning
TC	Technical Committee
ToC	Transfer of Control
TPG	Tyre Pressure Gauge
TPG DRM	TPG Discovery Request Message
TPG SNM	TPG Service Notification Message
TPG TCM	TPG Confirmation reservation Message
TPG TRM	TPG Reservation Message
TPMS	Tyres Pressure Monitoring System
TR	Technical Report
TTC	Time To Collision
TV	Target Vehicle
URL	Uniform Resource Locator
V2I	Vehicle to Infrastructure
V2P	Vehicle to Pedestrian
V2V	Vehicle to vehicle
V2X	Vehicle to X
VAM	Vulnerable Awareness Message
VBS	Vulnerable Basic Service
V-ITS	Vehicle ITS
VRU	Vulnerable Road User

4 Basic principles

4.1 Introduction

Basic principles are necessary to develop a common understanding of the current aspects which are driving the development of Intelligent Transport Systems (ITS) and then the specification of standards which are judged necessary to support their deployment.

Automated vehicles are robots which are controlled by Information and Communication Technologies. These robots are moving with a high dynamic in constrained environment delimited by road infrastructures or sometimes evolving out of them (e.g. for agriculture vehicles). Then the road safety is a key aspect which needs to be considered in priority.

Automated vehicle cannot be autonomous, they need to be assisted by the road infrastructure and need to stay always under the control of their users/owners (even remotely). They need to respect the existing traffic code and all other regulations which are applicable at the European and Member' states levels for transport systems.

ITS is a very complex domain which includes many different situations giving birth to a large diversity of use cases which need to be supported by ITS applications which have to be flexible enough to adapt to this large diversity.

4.2 ITS services, ITS applications, Use Cases, and Implementation Scenarios

4.2.1 Introduction

An ITS Service is intended to realise a specific transport related positive effect of any kind for a transport physical user (e.g. driver, for a non-ITS automated system). In principle a service is realized by an application. For the realization of the service, an application can use its own sensors but can also use data from other sources which provide their own services realized by applications. In Cooperative ITS (C-ITS, subset of ITS) for instance there are the warnings generated by one ITS-S and used by one other ITS-S. In this case there is an application which at the dissemination ITS-S is sending the warning to the other stations and at the receiving ITS-S an application which provides the information to the appropriate user. An ITS Service is user specific, which is realized by an application and could be realized based on information uses from other services realizing applications inside the ITS-S as well as by other ITS-Ss.

As ITS services are expected to be provided in different situations, they can be provided by ITS applications covering single, simple, more complex use cases under various conditions often identified by implementation scenarios (see figure 1). Use cases and associated implementation scenarios identify specific environmental conditions as well as all participants in a timely, positional, and relational situation in a detailed manner.

As the present document identifies the applications at high-level, only those implementation scenarios related needs which are relevant will be included as part of the use case needs in the present document. An ITS service could support a single or multiple use case(s).

For instance, a Road Work Warning (RWW) service could support a use case which ensures a safe way through the RWW but can also support a use case which informs road users about RWW so they can decide to take a different route; There are two completely different use cases from which the first is a C-ITS safety related use case while the second is not safety related. The first also has different system needs than the second. The present document recognized these aspects from a high-level perspective.

Figure 1 presents the relationship between ITS Service, ITS Application, use cases and implementation scenarios.

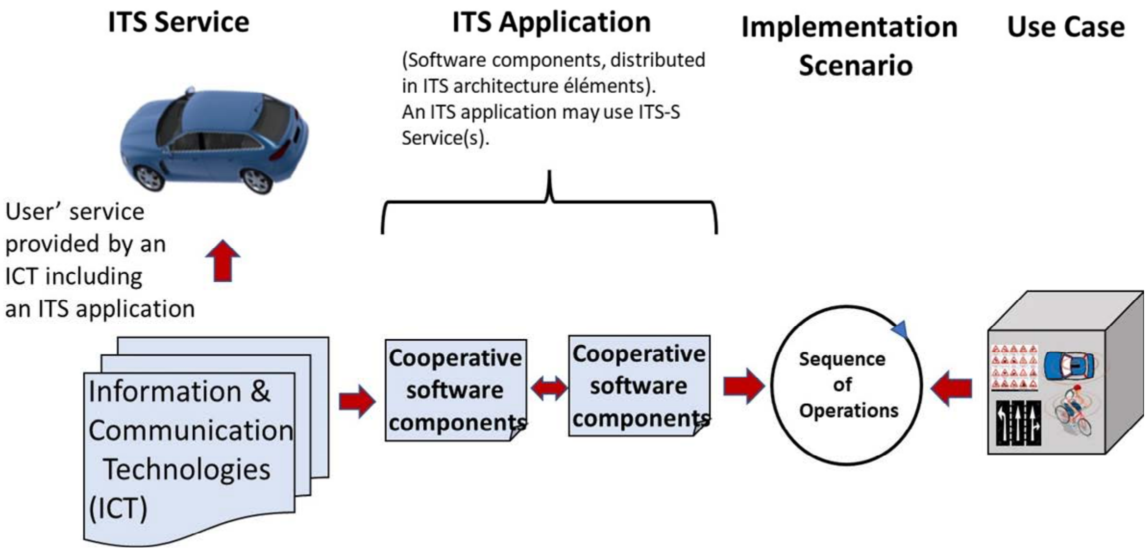


Figure 1: Relationship between ITS service, ITS application, use cases and implementation scenarios

4.2.2 ITS Services (ITSs)

ITS Services are all transport related. These can be logistics related, statistics, maintenance, safety, market specific or general. ICT systems can be tailored to a specific group of interested parties or can be general leading to different system requirements. At present there are several privately specified systems which do not require interoperability and therefore are not standardized. At present there is only one system which requires interoperability and that is Cooperative ITS. In future others could be identified.

4.2.3 Cooperative ITS (C-ITS)

Cooperative ITS is characterized by its information sharing mechanism. In Cooperative ITS there is no difference made between any of the participants in the information sharing and no one is excluded. In principle every participant is equal to any other and all have the same rights and obligations. There is no specific owner of the system, it is a free public system. To ensure the proper operation of such a system ITS-Ss should behave in a specific way and it should be possible to trust the received information. This ECOsystem specific need and the definition are not identified here but are in the related Release 2 specific documents.

Cooperation information sharing can be for the following reasons:

- To inform others of interesting events or presence of specific scenarios all non-safety,
- To inform others of safety relevant situations,

- To communicate about individual automotive movement interests with common safety relevance.

SAE J3216 [i.2] identifies Cooperative Driving Automation (CDA) aiming to improve the safety and flow of traffic and/or facilitate road operations by supporting the movement of multiple vehicles in proximity to one another.

4.2.4 ITS Applications

ITS Applications are pieces of software which are distributed in ITS architecture elements (VRU portable devices, vehicles, roadside equipment, and central equipment). These applications are realizing the ITS Services which are proposed to road users.

ITS Applications need to be supported by standard communication services which are enabling the exchange of information between their distributed elements which need to interact together during their operation.

4.2.5 Use Cases

Use cases are traffic situations which need the support of ICT to achieve one or several identified road users' goals. They include dynamic mobile objects (VRUs and vehicles) moving on identified road topologies and off-roads (e.g. for agricultural use cases). They also include static objects which are used on purpose for traffic management or are resulting from road hazards.

Several types of ITS architectures and ICTs can be used according to manufacturers' implementation choices.

4.2.6 Implementation Scenarios

Implementation scenarios are the integration of identified use cases with specific ICT solutions and ITS architectures which are selected by their suppliers.

As the selected ITS architecture is always a distributed one (i.e. ICTs at least in two elements of the ITS architecture), the interactions between the distributed elements needs to be interoperable and then require the availability of communication standards.

These communication standards are provided by the ITS Station (ITS-S) and have to be identified in implementation scenarios.

4.3 Safety, Active Safety and Passive-Safety

4.3.1 Introduction

Road safety is a key ITS service which needs to be offered to road users. Three different safety situations can be distinguished:

- Crash avoidance when considering the TTC (Time To Collision) and respective velocities of vehicles which are at risk of collision, it is still possible to act to avoid the collision. The latest possible action is then to trigger the Advanced Emergency Brake System (AEBS) of one or several vehicle(s) being at risk of collision.

- Pre-crash mitigation when it is not possible to avoid the crash between two or more vehicles. In this case according to TTC everything is achieved to reduce the effects of impacts on vehicles' occupants (adjusting seat belts, triggering relevant airbags, adjusting headrest, etc.).

- Post-crash (also called passive safety) which consists of triggering the emergency call and facilitate the rescue to reach as soon as possible the location of the crash.

4.3.2 Active safety - Crash Avoidance

Such active safety has the goal to avoid crashes between two or more mobile objects or between one mobile object and one static object.

To achieve such goal, the ITS architecture elements need cooperating to anticipate a risk of collision to be able to act in time to avoid it.

Anticipating a risk of collision and acting in time to avoid it requires to be able to predict such risk and estimate the Time To Collision (TTC) to verify that being given the local context (e.g. traffic, meteorological, human, technical, etc.) it will be possible to avoid the identified predicted collision.

Then, the goal of the active safety-crash avoidance ITS Application is to have the capability and means to avoid crashes between mobile objects (VRUs, Vehicles, etc.) and between mobile objects and static objects.

The AEBS (Automated Emergency Brake System) is typically a crash avoidance system which is already mandatory for many types of new vehicles' models. AEBS can be triggered by vehicle sensors (for example the front camera or lidar). Cooperative ITS enables the AEBS triggering from a remote ITS-S, providing an increased security level.

4.3.3 Active safety - Pre-crash mitigation

When it is not possible to avoid a crash, it can be possible to reduce as much as possible its effects on occupants of involved vehicles or VRUs.

Such goal requires also to predict and identify the risk of collision but, with a TTC which does not allow to act to avoid it. In such situation it is possible to be active to mitigate the effects of the collision on occupants of involved vehicles or on VRUs.

Pre-crash mitigation requires the availability of means in the involved vehicles which can be triggered in time for such purpose:

- Airbags which can be triggered several hundreds of milliseconds before the crash where it is necessary according to the predicted impacts.
- Seat Belts which can be adjusted according to the predicted impacts energies.
- Headrests which can be positioned according to the predicted impacts and their energies.
- Etc.

For VRUs, it is possible to trigger vehicle external mechanisms (e.g. airbags) to reduce/absorb the impact energy.

Then, the goal of the ITS Application is to actively mitigate the effect of an unavoidable collision on occupants of vehicles which are involved in the collision [i.4].

4.3.4 Passive Safety

Passive safety means that either the crash has not been avoided, but even if mitigated, it is necessary to trigger an emergency rescue because the impacts between mobile objects or between mobile and static object may have caused road users' injuries which need to be treated.

The main mean to be used is the emergency call (eCall) which enable to find the more appropriate rescue organization to be requested according to the location of impacted mobile object and other criteria associated to the impacts.

Moreover, when a rescue is triggered, it is necessary to facilitate the mobility of the rescue vehicles by creating emergency corridors.

Then, the goal of the ITS Application is to accelerate the arrival of rescue teams directly on the spot of a road accident.

4.3.5 Operational Safety Requirements

The system operational safety considers the system behaviour in abnormal situations of hardware/software failures (functional safety aspects), cyberattacks (security aspects) or human modification of the system (e.g. voluntary degradation of a specific vehicle function).

The main standardization supply to ITS applications is the provisioning of basic services consisting of disseminating standard messages which are received by ITS-S and used for specific purposes related to the targeted cooperation class.

Standard messages are received by vehicles which need to interpret them to discover the specific purpose associated to them. Receiving vehicles keep their responsibility to use a received message or not.

Before using a received message, this one can be verified when passing through the various layers of protocols being present in the selected communication profile:

- Then the security protocol verifies the authenticity of the source of the message and may detect a non-authorized source leading to a reject of the message and its signalling to relevant authorities.
- The facilities layer may also check the message payload which is used by the ITS application to decide how to use it to achieve its service purpose (i.e. increase the perception of the vehicle, decide to contribute or not to a collective action).

On this basis, the main operational safety risk is the reception of messages which are resulting from a defect of the originating source (hardware, software, data acquisition), or from a cyberattack attempting to manipulate the receiving ITS-S.

Several operational safety requirements can be derived to counter either a defect of the message source or a cyberattack:

OSR01: A message integrity check can be executed to verify that the message is complete and that its structure is complying to the reference standard.

OSR02: A message consistency check can be achieved to verify the existing consistency between relevant data elements values which are provided in the message.

OSR03: A message plausibility check can be achieved to verify the plausibility of the value of some relevant data elements either at the time of reception or in comparison between two consecutive messages.

OSR04: If the result of at least one of the verifications achieved is negative, the message needs to be discarded and a misbehaviour detection needs to be sent to the relevant security authority.

OSR05: According to the cooperation class (e.g. Cooperative driving class), a misbehaviour detection can also be signalled to partners of a collective action, including during its triggering phase.

4.4 Automation Levels

4.4.1 Introduction

Transport Automation is driven by vehicle automation but also has impact on transport infrastructure. Within the Automotive industry Automation levels have been defined and referred to as SAE levels.

According to SAE J3016 [i.1], automated vehicles can be classified into 6 levels from 0 to 5. Each level determines a level of automation:

- **Level 0: No driving automation.** Human does all driving.
- **Level 1: Driver assistance.** Longitudinal OR lateral vehicle motion control.
- **Level 2: Partial Driving Automation.** Longitudinal AND lateral vehicle motion control.
- **Level 3: Conditional automation.** The vehicle may fully take control of the driving responsibility under some conditions. A human driver is always present in the vehicle, hands on the steering wheel.
- **Level 4: High Driving Automation.** At this level, the vehicle can be driven by a human, but he does not ever need to be present.
- **Level 5: Full Driving Automation.** The vehicle can move everywhere without the support of a human driver. No need to have a steering wheel.

4.4.2 Partial Automation

Partial automation covers vehicles of SAE levels 1 to 3 which are equipped with ADASs which enable them to move during identified limited times in an automated driving mode.

The automated driving time periods are conditioned by the availability of roads which have the capabilities required to support the evolution of automated vehicles (e.g. required horizontal marking, required vertical signalling, RSE providing augmented perception in critical safety spots).

Longitudinal vehicle motion control needs the delimiting of lanes enabling the use of the Active Lane Keeping (ALK) ADAS which maintains the automated vehicle in road marked lanes. ACC and C-ACC are used to maintain the minimum time inter-distances between vehicles.

Lateral vehicle motion control needs the capability of the vehicle to eliminate blind spots and then to know via the road horizontal marking or/and the road vertical signalling, when it is possible/authorized for it changing of lane/road.

When in an automated driving mode, a vehicle needs to be capable of avoiding crash and for this purpose needs to be supported by the road infrastructure and have the required level of perception. The AEBS needs to be available if an automated emergency brake is required.

Even if both vehicle motion controls can be activated, one driver has to remain present in the automated vehicle to take back its driving control in case of necessity.

4.4.3 Full automation

Full automation corresponds to SAE levels 4 and 5.

Level 4 corresponds to the automated driving of the vehicle in a driving environment which was designed for such purpose. Then the vehicle can move in an automated driving mode only in environments which have the capabilities to support such automated driving mode.

Level 5 corresponds to the automated driving of the vehicle in all possible driving environments which are existing in its operation region. Such automation level can be made possible if both the vehicles and the road infrastructures offer the required capabilities (ODD: Operational Design Domain) to support such level of automation.

A level 4 and level 5 automated vehicle can be moving without a human driver in it.

But levels 4 and 5 automated vehicles moving without drivers in them need to be remotely supervised with the objective to remotely act (tele-operation) in case of failure (hardware/software defect) or malicious/cyberattack.

4.4.4 Cooperative Driving

From SAE J3216 [i.2], Cooperative Driving Automation (CDA) aims to improve the safety and flow of traffic and/or facilitate road operations by supporting the movement of multiple vehicles in proximity to one another.

This is accomplished, for example, by sharing information that can be used to influence (directly or indirectly) DDT performance by one or more nearby road users.

Cooperative Driving Automation distinguishes the four following classes of cooperation in order of increasing amount of cooperation:

- Status-sharing.
- Intent-sharing.
- Agreement-seeking.
- Prescriptive.

C2C-CC has published a guide for day 2 and beyond roadmap [i.3] which identifies 3 classes of cooperative services:

- Awareness Driving (day 1).
- Sensing Driving (day 2).
- Cooperative Driving (day 3 and day 3 +).

Differences exist between these two classes of cooperation approaches, though some similarities can be established:

- The SAE status-sharing is equivalent to the C2C-CC awareness driving as mainly status are exchanged between vehicles (e.g. CAMs, DENMs, CPMs) and between vehicles and roadside equipment (e.g. DENM, IVI, SPAT/MAP). However, the awareness driving (CAM) also contains some intent-sharing (e.g. intent to turn left or right, path prediction).
- The SAE intent-sharing could also be equivalent to C2C-CC awareness driving when optional data elements such as "path prediction" are used. This is possible at the CAM and VAM level.
- The SAE agreement-sharing and prescriptive can be covered by the C2C-CC cooperative driving. Several cooperation concepts are considered in ETSI TR 103 578 [i.12] Manoeuvre Coordination pre-study, while the prescriptive class seems necessary when a particular collision risk is detected or when a vehicle lawful interception request is received from a relevant authority. The prescriptive class may also be used for centralized traffic management applications.

4.4.5 Cooperation classes

From clause 4.4.4, the following principles of cooperation can be declined in three classes of cooperation:

- Awareness driving consisting to status-sharing. Vehicles as the road infrastructure share their environmental perceptions. This is increasing the autonomous perception of vehicles which is limited to their sensor's capabilities and other factors such as sensing limitations due to the road topology, weather conditions, fixed and mobile obstacles on the road, etc.
- Intent-sharing. Providing intents enables vehicles and VRUs to inform others of their short-term movements (for example, changes in their reference trajectories) with the objective to develop collective actions increasing the road safety and traffic efficiency. This class focuses on "prediction" of vehicle/VRU dynamic.
- Cooperative driving based on manoeuvre coordination. Once agreed or legally required, collective actions can be achieved via vehicles' cooperation or central tele-operation (for example by the road infrastructure or a central supervisor).

NOTE: Cooperative driving can be decomposed into more classes (for example: Agreement-Seeking and Prescriptive) depending on the respective traffic rights of road users and other stakeholders (police, emergency services, road operators, public transport operators, etc.) and the origin of the manoeuvre coordination service triggering.

4.4.6 Mixed traffic management

All vehicles' automated levels will be cohabiting (mixed traffic) for a long time on European roads:

- The deployment of fully automated vehicles will be slow as many conditions are required to become a reality (full deployment of C-ITS, capability of the road infrastructure, 5G full coverage, availability of accurate, complete digital maps, etc.).
- The life cycle of in-service vehicles is long (average between 10 to 15 years).
- The customer acceptability for automated vehicle is uncertain as many customers like driving vehicles especially powerful vehicles.
- The E.C does not foresee a full deployment of automated vehicles before 2050.

For a long time, in-service vehicles will exhibit various automated levels, from the basic one which are currently using the ABS or ESP to most elaborated ones of level 4 or 5.

Therefore, all in-service vehicles will not have the capability to cooperate. This is resulting to a mixed traffic management which requires to be considered at the ITS Applications level and their supported use cases and implementation scenarios.

Such mixed traffic situation is not specific to a given use case but will affect all use cases.

Several mixed traffic management requirements can be studied to cope with this long-term mixed traffic situation:

MTR01: The category of an in-service vehicle can be indicated in messages which are exchanged between cooperative vehicles (e.g. level of automation in CAMs).

MTR02: All mobile and static objects need to be detected and signalled by cooperative ITS-S (vehicles and RSUs) especially in areas offering a limited perception (e.g. intersections, road curves, high of a slop, perception obstacle, etc.).

MTR03: As a non-connected vehicle cannot be cooperating with others, the evolution of this one, when detected and signalled, needs to be monitored in real time to predict as much as possible its evolution.

MTR04: As a non-connected vehicle is likely a human driven one, it becomes necessary for cooperative vehicles to consider the human factors, when the vehicle can be detected and signalled, to decide further actions.

5 ITS Services, Applications and use cases

5.1 Introduction

ITS Applications are developed to provide ITS services to road users. Often, ITS Applications are pieces of software which can be downloaded and updated in relevant functional entities to provide the ITS Services. ITS Applications are generally applicable to a generic sample of use cases.

The present document focuses on ITS Applications (Basic Set of Applications) providing ITS Services in particular mobility situations identified as use cases.

ITS Applications are generally distributed in several functional categories (VRUs' devices, vehicles' On-Board Units, Roadside Units, Central systems) which can be in the different functional categories of the ITS reference architecture. ITS Applications are supported by standard ITS-Stations (ITS-S) which provide them standard basic services to achieve their functional and operational objectives.

ITS applications are regrouped in clause 5 within ITS services. ITS applications are summarized (high level description) and generic functional and system requirements are provided for each one. Examples of implementation aspects are then provided.

5.2 Partial and high automation

5.2.1 ITS Service introduction

ITS applications categories "Partial Automation" make use of ITS service to trigger and control automated reactions at vehicles with low (i.e. L1 - L2 vehicles where the driver is still in charge of driving and monitoring tasks) as well as high automation capabilities (L3 + vehicles where the driver is released partially or totally from its monitoring and driving responsibilities). In this context, vehicles V2X communication and ITS-S services extend the capabilities of traditional ADASs and automated functions providing longer and non-line of sight detection ranges, as well as explicit communication of information between senders and receivers.

It has to be noted that the level of the vehicle automation is depending on:

- The availability of ADASs capabilities.
- The activation of these ADASs capabilities. Even if an ADAS capability is available at the level of the vehicle, this one could not be activated to leave to the driver the pleasure to drive its vehicle if requested.

It has also to be noted that the vehicle trajectory can be totally automated according to activated ADASs. Then the vehicle trajectory can be influenced by acting on relevant ADASs. This is something to be considered at the level of manoeuvres' coordination service.

5.2.2 Hazardous Location Notification - Vehicle Assistance Use Case

5.2.2.1 High level description

The specific goal of this use case is to provide ITS-S applications at receiving vehicles with more time and information to better assist semi-automated (ADAS) or automated reactions in presence of unexpected road hazards. A transmitting ITS-S notifies incoming traffic about occurrence, details, and evolution of a hazardous situation via DENMs. ITS-S applications at receiving vehicles process the information contained in DENMs, run a relevance check to understand if a given automated reaction is needed and, depending on the type and details of the hazards, the current vehicle status, and relative dynamics, apply the most suitable reaction.

Figure 2 shows a situation which is at the origin of a hazardous location notification. A road operator' stationary patroller (acting as an RSU) signals the road hazard and may guide approaching vehicles to drive round the obstacle.

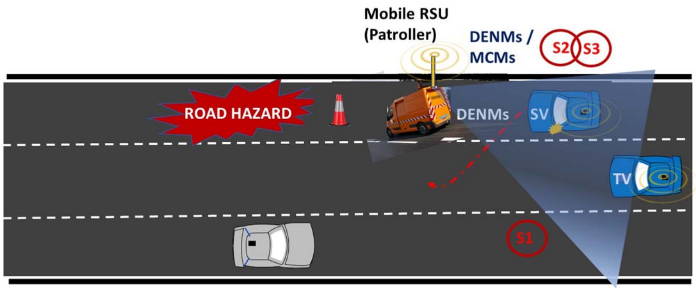


Figure 2: Hazardous location notification use case

5.2.2.2 Possible ITS architecture and ITS-S services

Architecture A: In this first architecture the use case runs among vehicles only. A transmitting vehicle triggers transmission of DENMs after detection of a hazardous situation and continuously updates the DENM content to describe possible evolution of the hazardous situation or its contextualization to the driving environment (e.g. lane, zone, road configuration where the hazard exists). One or multiple receiving vehicles approach the hazard location.

Architecture B: In this second architecture the use case runs with the help of a roadside ITS-S (figure 2). the hazardous situation is detected, communicated, and updated by a roadside ITS-S.

ITS-S services:

Two basic services can be used to signal and guide approaching cooperative vehicles:

- The Decentralized Environmental Notification Service (DENS) which signals the road hazard to approaching cooperative vehicles.
- The Manoeuvre Coordination Service (MCS) which may guide approaching cooperative vehicles to safely overtake the obstacle.

5.2.2.3 Possible implementation scenarios

Implementation Scenario S1:

The first implementation option refers to Architecture A. The DENMs transmitted by the vehicle ITS-S reflect the type of hazard, the location where it applies, the area and traffic direction where vehicles have to be aware of it, possible additional information that can help receiving vehicles to take reaction decisions (e.g. lane or geographical zone where the event is occurring, the speed limit that should be applied when approaching the event, the road configuration of the road segments where the event happens).

Implementation Scenario S2:

This second implementation option refers to architecture B. A road operator patroller was sent to secure a detected road hazard. This patroller is acting as an RSU disseminating DENMs to approaching cooperative vehicles. As for S1, data elements are received by approaching cooperative vehicles, are analysed, and used if judged relevant.

Implementation Scenario S3:

This third implementation option also refers to Architecture B. The Mobile RSU (stationary patroller) owns autonomous perception capabilities enabling it guiding the achievement of a collective action facilitating the overtaking of the road hazard. This can be achieved using the Manoeuvre Coordination Service (MCS). In such case, the RSU may propose an offer to start a collective action creating an insertion gap enabling the subject vehicle SV to overtake the road hazard. If accepted, a cooperative target vehicle reduces its velocity to create the insertion gap and the SV may use it to change of lane.

5.2.2.4 Implementation scenario flow diagram

Figure 3 shows a flow diagram model (model 1) which describes the messages exchanges between cooperative ITS-Ss.

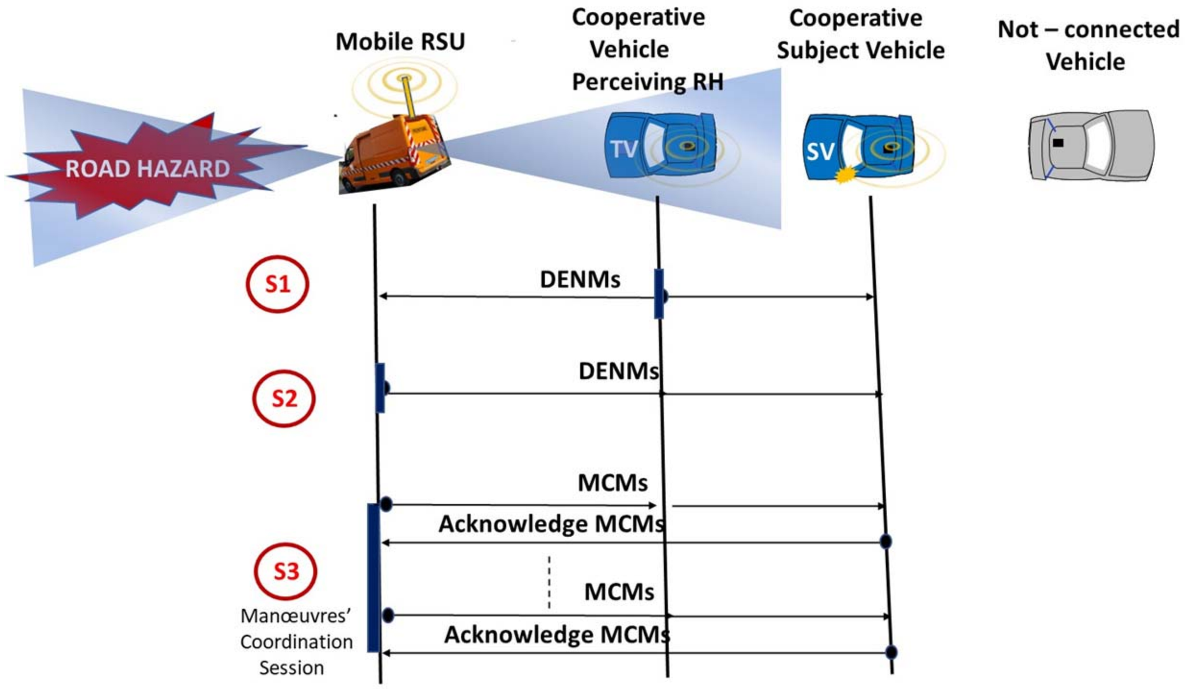


Figure 3: Flow diagram model 1, combining DENMs broadcasting and MCMs broadcasting

5.2.2.5 Possible implementation scenarios options

Scenarios 1 &2:

According to respective driving modes of cooperative vehicles and their capabilities, a driving mode transition can be beneficial (e.g. from human driven to automated) and the dissemination of new DENMs could be necessary to inform other nearby cooperative vehicles of undertaken manoeuvre.

Scenario 3:

In this scenario the Agreement-Seeking concept can be used by the mobile RSU which provides a MC Offer to the cooperative Subject Vehicle (SV). This use of the MCS can be conditioned by a high traffic density situation in the middle lane.

If the TTC between the subject vehicle approaching with an excessive speed and the road hazard is short (e.g. less than 2 seconds), the mobile RSU may use the prescriptive concept sending an emergency brake instruction to avoid collision of the subject vehicle with the road hazard.

5.2.3 Cooperative Adaptive Cruise Control (C-ACC) use case

5.2.3.1 High level description

The Cooperative Adaptive Cruise Control (C-ACC) ITS application uses continuous communication from a target vehicle to a subject vehicle so that the subject vehicle can dynamically adapt its time gap to the target vehicle and keep it constant to a reduced value which would not be safely possible if only using inputs from front sensors. Applying V2X as an additional real-time input to longitudinal control is demonstrated to improve traffic flow and driving convenience thanks to a reduction of unnecessary braking and throttle manoeuvres.

Figure 4 shows a situation illustrating the C-ACC use case.

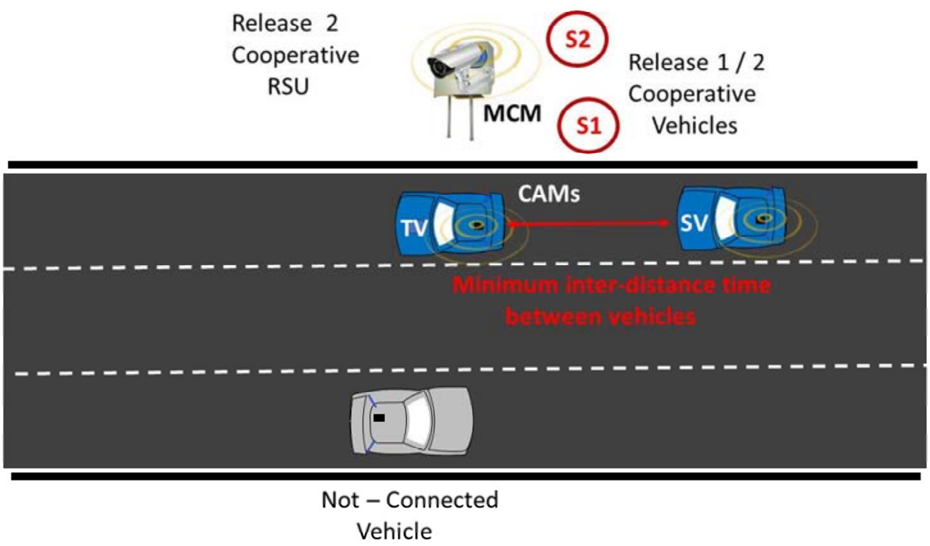


Figure 4: Cooperative Adaptive Cruise Control use case

5.2.3.2 Possible ITS architecture and ITS-S services

The road safety minimum performance requirements lead to focus on the two following possible ITS architectures:

- V2V Cooperation.
- I2V Cooperation combined with V2V.

Possible ITS-S Services:

- CAS provided by the target vehicle.
- MCS provided by the RSU.

5.2.3.3 Possible implementation scenarios

S1: Target Vehicle broadcasts CAMs:

The first ITS-S implementation scenario foresees presence of only two communicating vehicles. A Subject Vehicle (SV) follows a so-called Target Vehicle (TV) and continuously receives from it, CAM messages containing real-time position, as well as current and predicted dynamics.

S2: Target Vehicle broadcasts CAMs and RSU broadcasts MCMs:

In this second ITS-S implementation scenario, the two vehicles are complemented by a roadside ITS-S that might provide information influencing their longitudinal control such as regulatory speed limits, speed suggestions, values of the vehicles' minimum time inter-distance, etc.

5.2.3.4 Implementation scenario flow diagram

The following flow diagram (figure 5) illustrates described ITS implementation scenarios.

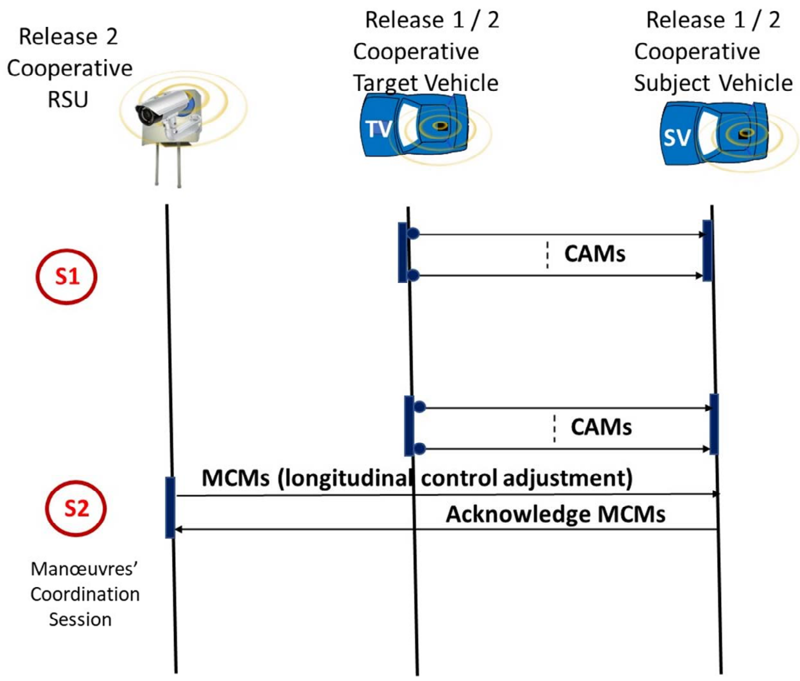


Figure 5: Flow diagram Model 2, combining CAMs broadcasting with MCMs broadcasting

5.2.3.5 Possible implementation scenarios options

In scenario 1, the degree of longitudinal control of the two vehicles are related to the information provided by the CAMs. It would be more efficient if the CAM contains the trajectory prediction of the Target vehicle, so enabling the Subject Vehicle to better anticipate its trajectory evolutions.

In scenario 2, the RSU may adjust the longitudinal control of vehicles according to perceived traffic density.

5.2.4 C-ACC string use case

5.2.4.1 High level description

The Cooperative Adaptive Cruise Control (C-ACC) ITS application can be extended if the subject vehicle additionally considers information received from other vehicles preceding target vehicle directly in front of it. If more than two vehicles implement the C-ACC ITS-S application and each of them considers the information of the other vehicles in front, a string of C-ACC vehicles is realized.

Figure 6 shows a situation illustrating the C-ACC string use case.

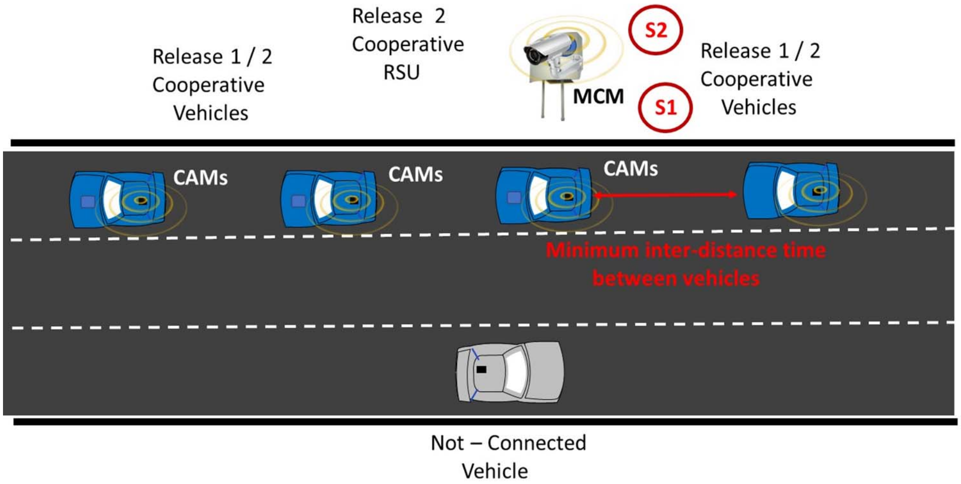


Figure 6: C-ACC string use case

5.2.4.2 Possible ITS architecture and ITS-S services

As for the previous C-ACC use case, the two following possible ITS architectures are considered:

- V2V Cooperation.
- I2V Cooperation combined with V2V.

Possible ITS-S Services:

- CAS provided by all cooperative vehicles ahead of the subject vehicle.
- MCS provided by the RSU.

5.2.4.3 Possible implementation scenarios

S1: All cooperative vehicles ahead of the subject vehicles broadcast CAMs:

In this first scenario multiple communicating vehicles run the C-ACC ITS application. A subject vehicle follows a so-called target vehicle and continuously receives CAMs from it as well as from the other C-ACC vehicles ahead in the string.

S2: All cooperative vehicles ahead of the subject vehicle broadcast CAMs and RSU broadcasts MCMs:

In this second scenario, the multiple vehicles are complemented by a roadside ITS-S that might provide information influencing their longitudinal control such as regulatory speed limits, speed suggestion, minimum vehicles' inter-distance time, etc.

5.2.4.4 Implementation scenario flow diagram

The flow diagram Model 2, in figure 5 is applicable to a string of cooperative vehicles.

5.2.4.5 Possible implementation scenarios options

In scenario 1, the degree of longitudinal control of a subject vehicle is related to the information provided by the received CAMs. It would be more efficient if the CAM contains the trajectory prediction of the Target vehicle, so enabling the Subject Vehicle to better anticipate its trajectory evolutions. Moreover, when the number of ahead cooperative vehicles are increasing the perception of the subject vehicle relatively to the evolution of the traffic becomes more efficient (e.g. detecting and signalling shockwaves).

In scenario 2, the RSU may adjust the longitudinal control of vehicles according to perceived traffic density and regularity.

5.2.5 Cooperative Adaptive Emergency Brake System (C-AEBS) use case

5.2.5.1 High level description

A Subject Vehicle (SV) applies an automated braking to avoid a crash with another road user, (e.g. a hard braking vehicle). The situation is detected by messages received from Target Vehicle (TV) or other ITS-Ss. The automated braking in the subject vehicle is issued when the time to collision falls below an application threshold (e.g. 2 seconds). This is a semi-automated function, as the driver is requested to be in the loop. The messages from target vehicles can be extended with safety containers for functional safety reasons.

Figure 7 shows a situation illustrating the C-AEBS use case.

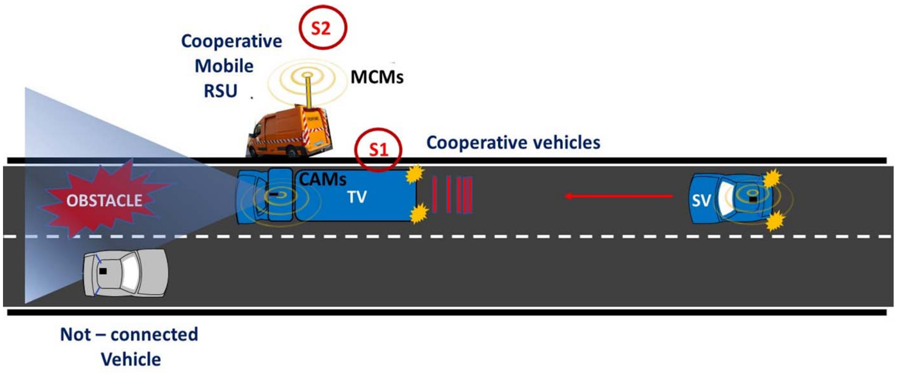


Figure 7: C-AEBS use case

5.2.5.2 Possible ITS architecture and ITS-S services

The road safety minimum performance requirements lead to focus on the two following possible ITS architectures:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- CAS.
- MCS.

5.2.5.3 Possible implementation scenarios

S1: V2V consecutive to the reception of CAMs:

The Target Vehicle (TV) detects an obstacle on the road which cannot be overtaken because the arrival of another vehicle on the opposite lane. It is then obliged to brake hardly to wait for an opening gap to overtake the obstacle. The subject vehicle detects this strong deceleration of the target vehicles via the received CAMs. According to its TTC value, the subject vehicle may be obliged to trigger its C-AEBS to avoid a collision with the Target Vehicle.

S2: I2V consecutive to the reception of MCMs:

A mobile RSU protects the area which is closed by an obstacle and broadcasts MCMs to assist arriving Subject Vehicles either to stop in front of the obstacle or overtake it. If the TTC of subject vehicle requires an emergency brake, the mobile RSU prescribes it to avoid a collision with the obstacle or another vehicle (e.g. a not - connected one) waiting in front of the obstacle.

5.2.5.4 Implementation scenario flow diagram

The flow diagram Model 2, in figure 5 is applicable to this use case.

5.2.5.5 Possible implementation scenarios options

The S2 option can be using an Agreement Seeking concept or a Prescriptive concept according the TTC value and the manoeuvres to be executed (e.g. slowing down, overtaking, or emergency brake).

5.2.6 Advanced Pre-Crash sensing use case

5.2.6.1 High level description

This use case describes the process for information provided by a vehicle V1 or a RSU, when a critical situation is detected, via DENMs including use case specific extensions in an a-la-carte container [i.6]. Each receiving vehicle may activate its Pre-Crash measures when it assumes itself to be under risk and the situation is considered as sufficiently critical (i.e. TTC < 1 second).

Figure 8 shows a situation illustrating the Advanced Pre-Crash sensing use case.

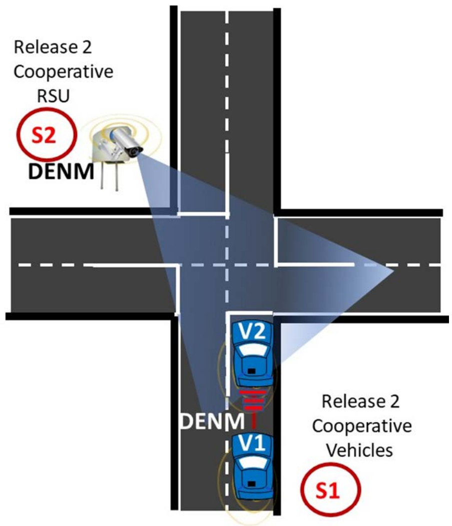


Figure 8: Advanced Pre-Crash sensing use case

5.2.6.2 Possible ITS architecture and ITS-S services

The road safety minimum performance requirements lead to prefer the two following possible ITS architectures:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- Extension of the DEN S, using the "a la carte container" in DENMs [i.6] to characterize the post-crash impacts.

5.2.6.3 Possible implementation scenarios

S1: V2V, V1 provides information about post-crash prediction:

Cooperative Vehicle V1 detects a high probability of a collision with the vehicle V2 and then broadcasts extended DENMs providing information about the predicted impacts of the collision.

Upon reception of extended DENMs, the cooperative vehicle V2 triggers occupants' protection measures (airbags activation, adjustment of seat belts and headrests, etc.) to mitigate the impacts of the collision on them.

S2: I2V, RSU provides information about post-crash prediction:

The cooperative RSU detects a high probability of a collision between the vehicles V1 and V2 (i.e. via the reception of their CAMs) and then broadcasts extended DENMs providing information about the predicted impacts of the collision.

Upon reception of extended DENMs, the cooperative vehicle V2 triggers occupants' protection measures (airbags activation, adjustment of seat belts and headrests, etc.) to mitigate the impacts of the collision on them.

5.2.6.4 Implementation scenario flow diagram

The following flow diagram (figure 9) illustrates the described implementation scenarios.

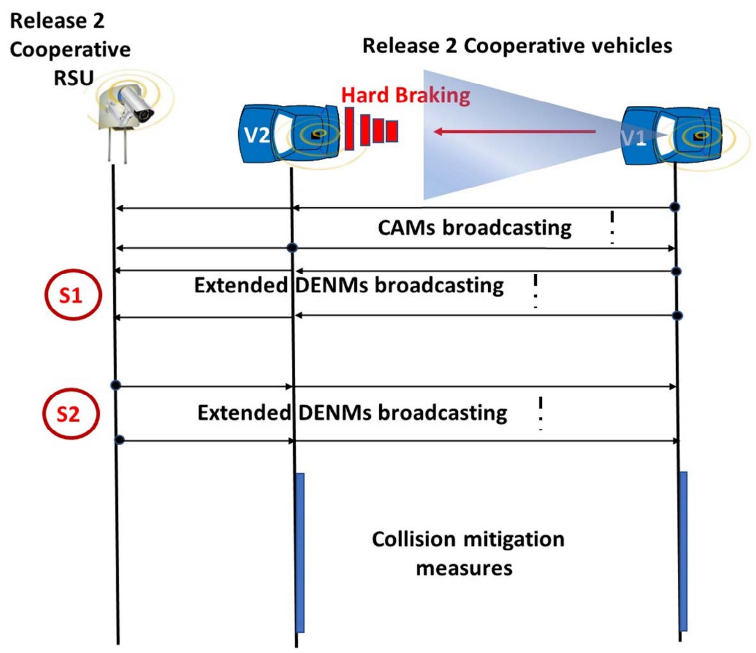


Figure 9: Flow diagram Model 3, applicable to the pre-crash sensing use case

5.2.6.5 Possible implementation scenarios options

See ETSI TR 103 832 [i.4].

The new release 2.2.1 of DENM [i.6] provides the standards evolutions for the support of this new application.

5.2.7 Cooperative Active Lane Keeping (C-ALK) use case

5.2.7.1 High level description

The Cooperative Adaptive Lane Keeping (C-ALK) ITS application can be used to protect VRUs in shared areas when occupied by VRUs. In such case, the CCAM vehicles can be notified/instructed to remain in their lane if the shared VRUs protected area is signalled as occupied by VRUs.

NOTE: This use case is also applicable to priority shuttle lane.

More generic use cases are possible when a change of lane is not authorized.

Figure 10 shows a situation illustrating the Active Lane Keeping use case.

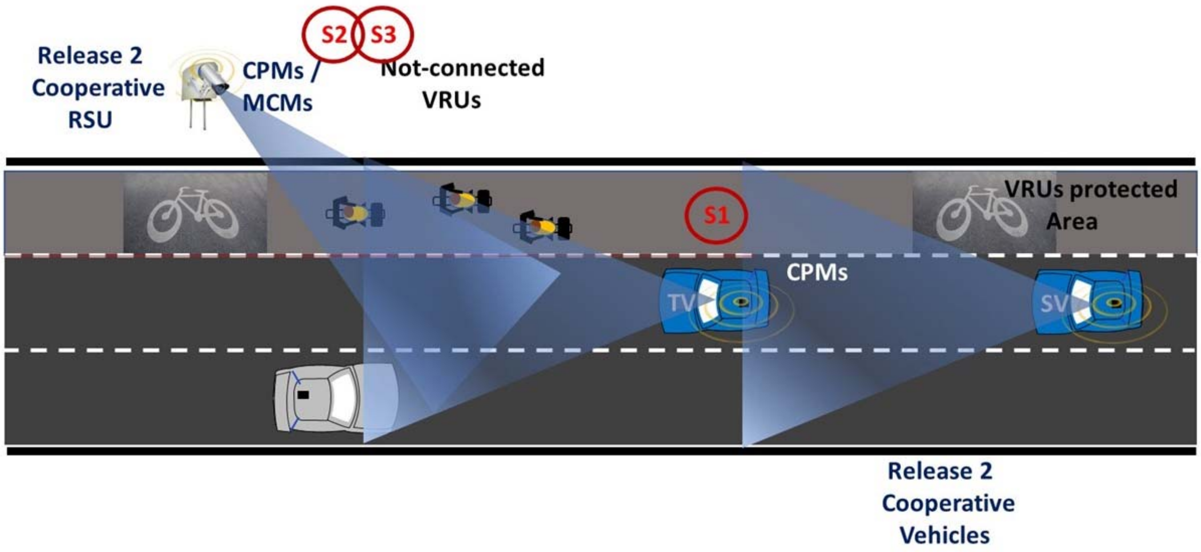


Figure 10: Cooperative Active Lane Keeping use case

A specialization of this use case is protection of a priority lane for autonomous shuttles, buses, etc. In a street with a priority lane, the RSUs instruct the priority vehicle (e.g. shuttle) to change to the protected priority lane. Non-priority vehicles can occupy the lane when no priority vehicles are in but, they are instructed to get out of the priority lane if a priority vehicle is detected approaching.

5.2.7.2 Possible ITS architecture and ITS-S services

The road safety minimum performance requirements lead to preferably focus on the two following possible ITS architectures:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- CPS provided by a release 2 cooperative Target Vehicle (TV).
- CPS provided by a release 2 cooperative RSU.
- MCS provide by a cooperative RSU.

5.2.7.3 Possible implementation scenarios

S1: A release 2 cooperative Target Vehicle signals VRUs using CPS:

In this first scenario the release 2 cooperative Target Vehicle (TV) perceives VRUs progressing on the VRUs protected area. TV signals perceived VRUs broadcasting CPMs.

Upon reception of CPMs, the Subject Vehicle (SV) may decide to transit to automated driving and to activate its Active Lane Keeping assistance to avoid entering the VRUs protected area.

S2: A release 2 cooperative RSU signals VRUs using CPS:

In this second scenario, the release 2 cooperative RSU perceives a group of VRUs progressing on the VRUs protected area. Then the RSU signals them broadcasting CPMs.

Upon reception of CPMs, the Subject Vehicle (SV) may decide to transit to automated driving and to activate its Active Lane Keeping assistance to avoid entering the VRUs protected area.

S3: A release 2 cooperative RSU requests the active lane keeping using MCS:

In this third scenario, the RSU requests to approaching release 2 cooperative Subject Vehicles (SVs) to transit to the automated driving mode and then activate their active lane keeping assistance, to avoid collision with VRUs.

5.2.7.4 Implementation scenario flow diagram

The following flow diagram (figure 11) illustrates described ITS implementation scenarios.

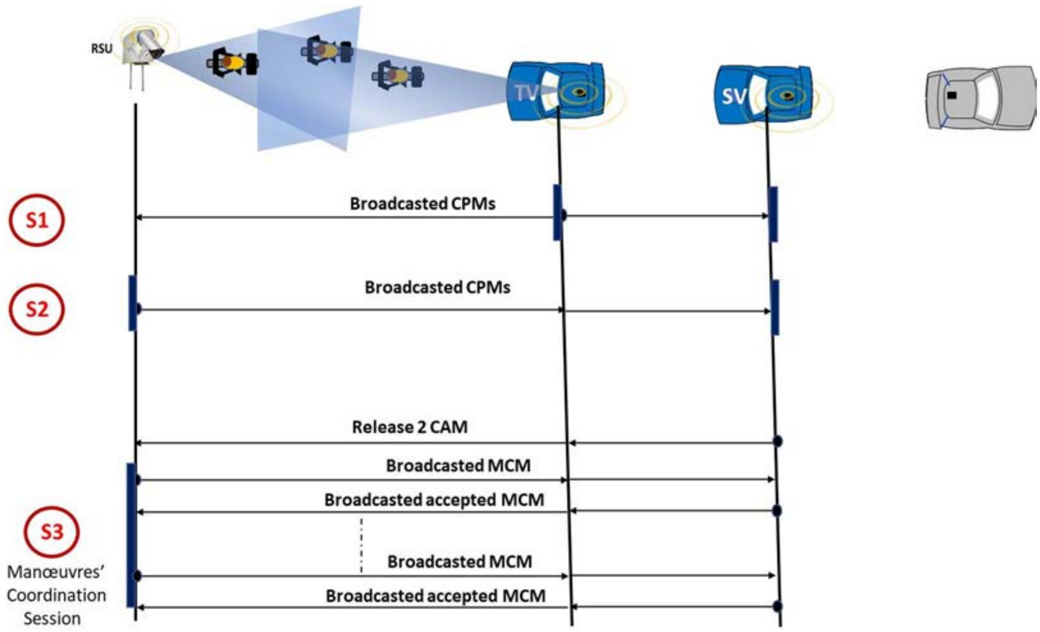


Figure 11: Flow diagram Model 4, combining CPMs broadcasting with MCMs broadcasting

5.2.7.5 Possible implementation scenarios options

In scenario 1 and 2, the subject vehicle may decide to activate its active lane keeping if available.

In scenario 3, the MC Concept can be prescriptive, instructing the subject vehicle to activate its active lane keeping if available. A release 2 CAM may provide information about the Subject Vehicle ALK capabilities and current state.

5.2.8 Cooperative Intelligent Speed Adaptation (C-ISA) use case

5.2.8.1 High level description

The Cooperative Intelligent Speed Adaptation ITS application can be used to avoid collision or better manage the traffic in adverse contextual conditions (e.g. adverse weather conditions, adverse traffic conditions, etc.). In such case, the CCAM vehicles can be notified/instructed to adjust their speeds to the adverse contextual conditions.

Figure 12 shows a situation illustrating the Intelligent Speed Adaptation use case.

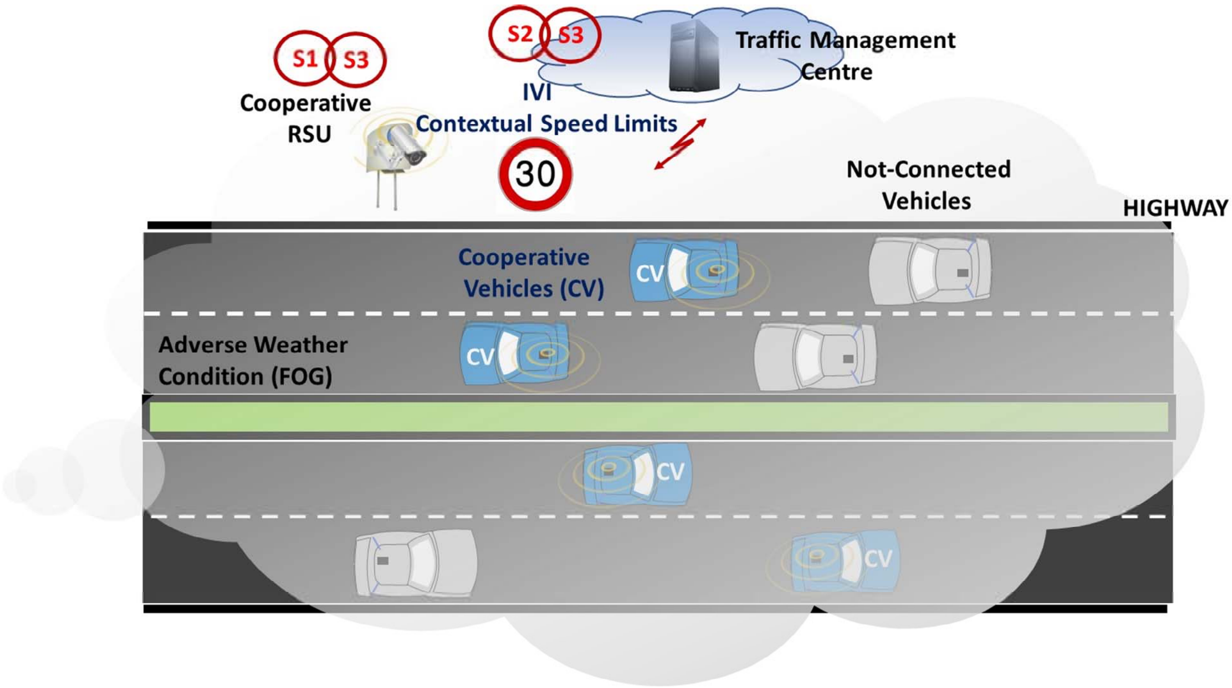


Figure 12: Cooperative Intelligent Speed Adaptation use case

5.2.8.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seems the more appropriate for this use case:

- I2V Cooperation.
- C2V Cooperation.

Possible ITS-S Services:

- Contextual Speed Limit provided by RSU using IVI.
- Contextual Speed Limit provided by a central traffic management centre using IVI.
- Manoeuvres' Coordination messages provided by a local RSU or a centre.

5.2.8.3 Possible implementation scenarios

S1: A RSU broadcasts contextual speed limits using IVI:

The cooperative RSU disseminates contextual speed limits using IVI messages. All receiving cooperative vehicles adjust their speed below the speed limit.

S2: A central traffic management centre disseminates contextual speed limits using IVI:

The central management system disseminates contextual speed limits using IVI messages. All receiving cooperative vehicles adjust their speed below the speed limit.

S3: RSU or centre provides MCMs to synchronize Cooperative Vehicles:

MCS can be used by the cooperative RSU or the central management system to synchronize key cooperative vehicles (e.g. vehicles moving side by side on the two lanes of each highway direction) at a given speed. Such synchronization would automatically constrain not-connected vehicles to remain behind the synchronized cooperative vehicles and so respect their adjusted speeds.

5.2.8.4 Implementation scenario flow diagram

The following flow diagram (figure 13) illustrates described ITS implementation scenarios.

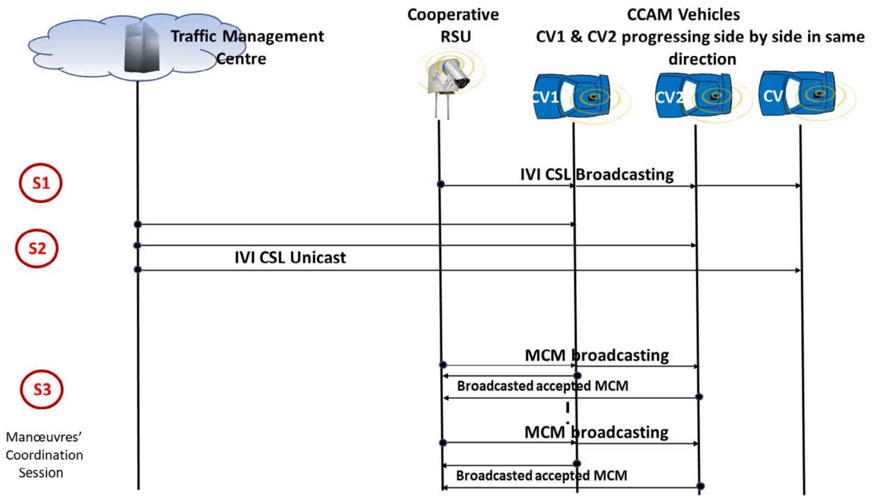


Figure 13: Flow diagram Model 5, combining IVI CSL broadcasting with MCMs broadcasting

5.2.8.5 Possible implementation scenarios options

The S3 option is only possible when the density of cooperative vehicles reaches a certain level to be identified.

5.2.9 Cooperative Tyre Pressure Adjustment System use case

5.2.9.1 High level description

A Subject Vehicle (SV) is informed (Orange or red flag) by its Tyre Pressure Monitoring System (TPMS) that the pressure of one of its tyres is not properly adjusted and needs to be checked and corrected as soon as possible for safety and environmental protection purposes. The subject vehicle task is now to find a relevant "Tyres Pressure Gauge (TPG) station" as near as possible its local position. Such station is a POI which can be automatically signalled (Push mode) or requested by the subject vehicle (Pull mode).

Figure 14 shows a situation illustrating the Tyre Pressure Adjustment System use case.

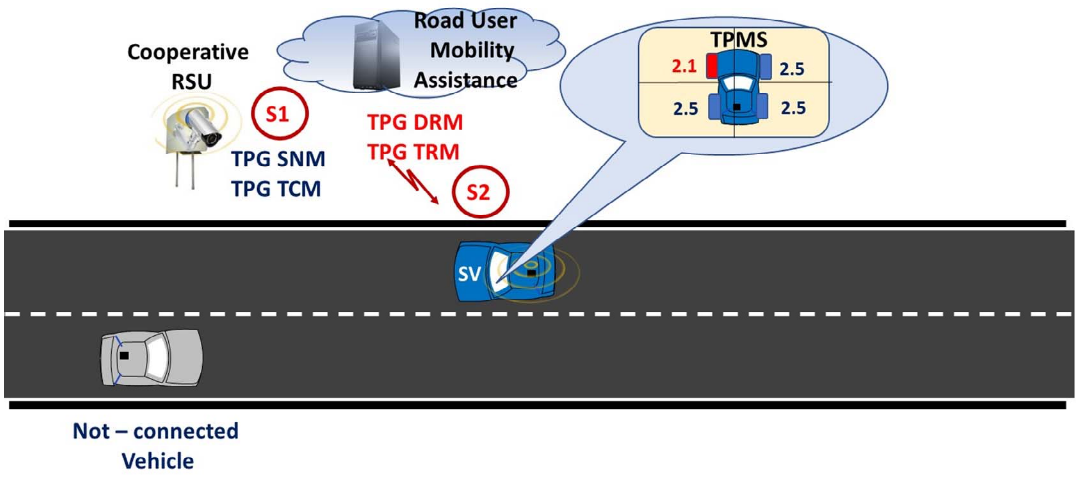


Figure 14: Cooperative Tyre Pressure Adjustment System use case

5.2.9.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V Cooperation.
- C2V Cooperation.

Possible ITS-S Services:

- TPG Discovery Request Message (DRM).
- TPG Service Notification Message (SNM).

5.2.9.3 Possible implementation scenarios

S1: I2V/C2V TPG Discovery Request Message (DRM):

The detection of a tyre pressure defect by the TPMS triggers the transmission of a TPG Discovery Request Message to a local RSU or a central system. The relevant RSU or central system provides the nearest TPG station to the requesting subject vehicle which can reserve a time slot (TPG TRM and TPG TCM) for adjusting its tyres' pressures.

S2: I2V/C2V TPG Service Notification Message (SNM):

A subject vehicle detecting a tyre pressure defect has received a TPG SNM from a local RSU or a central system indicating the availability of the nearest TPG.

station. Then the subject vehicle may reserve a time slot for Tyre pressure adjustment.

5.2.9.4 Implementation scenario flow diagram

The following flow diagram (figure 15) illustrates described ITS implementation scenarios.

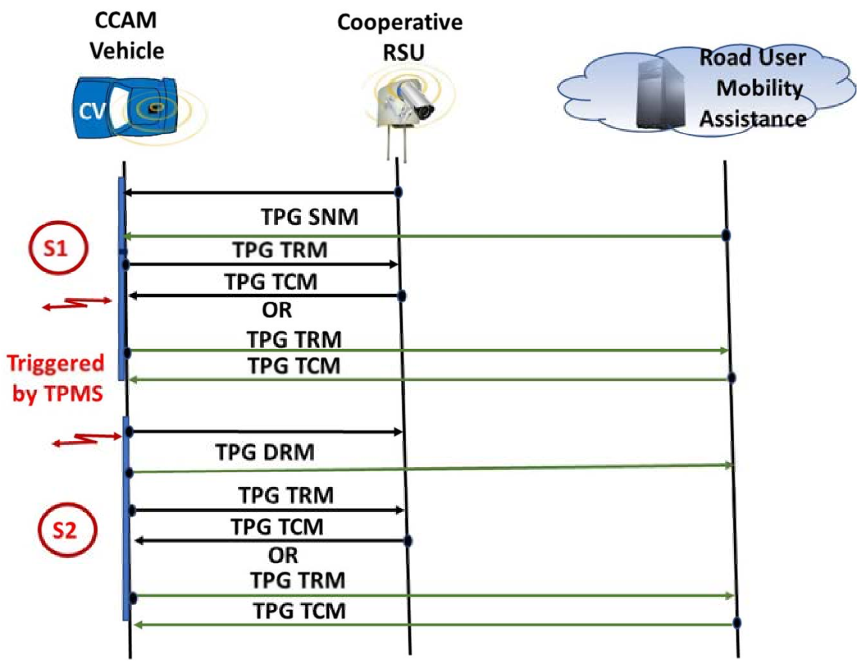


Figure 15: Flow diagram Model 6, applicable to the cooperative tyre pressure adjustment use case

5.2.9.5 Possible implementation scenarios options

Depending on the defective tyre pressure value, if this one is more assessed as a tyre puncture, the right POI is not a TPG station but a dealer garage to be able to repair a puncture.

5.2.10 Cooperative Vehicle Energy Critical Situation Assistance use case

5.2.10.1 High level description

A Subject Vehicle (SV) is informed (Orange or red flag) by its Available Energy Monitoring System of a "low autonomy" situation requiring an urgent supply of energy. The subject vehicle task is now to find a relevant "energy supply station" as near as possible its local position. Such station is a POI which can be automatically signalled (Push mode) or requested by the subject vehicle (Pull mode).

The transition to electrically propelled vehicles requires information on the availability of reloading electrical stations and hydrogen stations.

Figure 16 shows a situation illustrating the Vehicle Energy Critical Situation Assistance use case.

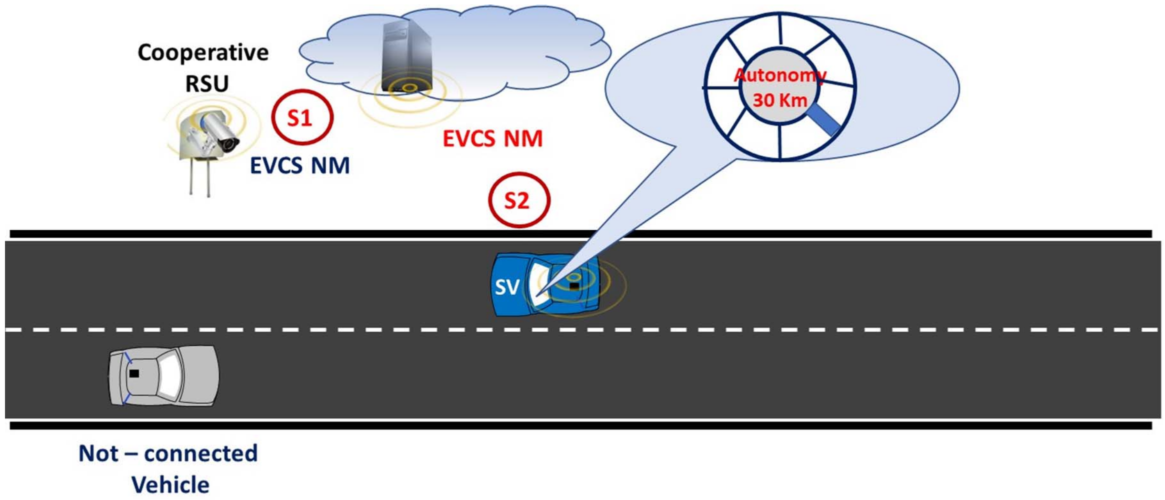


Figure 16: Cooperative Vehicle Energy Critical Situation Assistance use case

5.2.10.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seems to be the more appropriate ones for this use case:

- I2V Cooperation.
- C2V Cooperation.

Possible ITS-S Services:

- This example focuses on EV charging but could be extended to any other types of energies.

5.2.10.3 Possible implementation scenarios

S1: I2V Energy Supply Service Notification Message:

A local RSU informs about the local presence of EV charging spots and their respective status (i.e. type of connectors, prices, waiting times, etc.). This information can be memorized by receiving EVs to be used in case of necessity.

S2: C2V Energy Supply Service Notification Message:

A central system collects in real time information about the EVCSs present in its responsibility area. Then the central system provides real time information to EVs.

5.2.10.4 Implementation scenario flow diagram

The flow diagram Model 6, in figure 15 is applicable to this use case using specified messages.

5.2.10.5 Possible implementation scenarios options

The current ETSI TS 101 556-1 [i.7] needs to be revised to improve the interactions between the EV and other ITS-S.

It also needs to be revised to develop a more generic approach, considering that because the energy transition which is required by climate change is leading to a deep, continuous transformation of the energy distribution:

- Continuous deployment of new electrical charging spots.
- Continuous deployment of liquid, compressed hydrogen distribution.
- Progressive reduction of fossil energies being at the origin of greenhouse gaz.

5.2.11 Infrastructure support for ADS use case

5.2.11.1 High level description

Road infrastructure support to Automated Driving Systems (ADS) is important to allow vehicles to stay inside their Operational Design Domain (ODD) as long as possible, and/or to enlarge their ODD. In fact, both partly and fully automated vehicles will need additional support from infrastructure beyond the vehicle's sensor capability to maintain higher functions of automation for longer periods in time and longer stretches of road network.

Early attempts were focused on vehicle metrics like SAE level, but infrastructure soon realized that it cannot decide on levels of automation or the automated mobility ODD by itself, shifting its focus more on concepts like ISAD (Infrastructure Support levels for Automated Driving, see CEN/TR 17828 [i.10]). These levels include both the physical and visible infrastructure support (level E) as well as the various levels of digital support (level D to A). While being a step in the right direction, the concept of levels still leaves the infrastructure in charge of a metric ultimately to be decided upon by vehicles. The approach therefore needs to be changed to an information layer, providing vehicles with the information about all available data, services and measures taken by or made available from infrastructure to support higher levels of automation, leaving the final decision about the chosen level of automation to the vehicle, which is ultimately the only entity that can oversee its own ODD.

Based on this it would be beneficial that information about the availability of infrastructure support services would be provided to vehicles (ADS) in real-time so to make them aware of the infrastructure support that may avoid an ODD-exit and a consequent Minimum Risk Manoeuvre or Transition of Control (see also CEN/TR 17828 [i.10] clause 4.4). This information represents meta-information, i.e. information about the availability of information, and not the information itself which may be provided by other ITS Messages. The information layer itself will need to transport many diverse types of information, from different forms of digital C-ITS or ITS services, to the various physical measures and marking taken or present on the road network.

5.2.11.2 Possible ITS architecture and ITS-S services

This use application considers only the road infrastructure cooperation with vehicles:

- I2V Cooperation.

Possible ITS-S Services:

- I2V IVIM (extension).

5.2.11.3 Possible implementation scenarios

S1: I2V Cooperation:

Infrastructure RSUs send IVIM regarding the availability of infrastructure support information for automated driving systems, a matrix of available digital services and physical measures.

The vehicle uses both the information about the available infrastructure support measures as well as the data sources behind this information to decide on its level of automation within its own ODD.

5.3 CCAM augmented perception

5.3.1 ITS service introduction

As identified in clause 4.4.6, non-connected mobile objects such as vehicles and Vulnerable Road Users (VRUs) will cohabit with partially and fully automated vehicles for a long time. Non-connected mobile objects can only be perceived by the autonomous perception system of other vehicles and VRUs which have well-known limitations relatively to their perception capabilities (distance, coverage, etc.) and the environmental context in which they are moving (traffic density, particular road topographies, meteorological conditions, etc.).

One way to augment the autonomous perception of non-connected dynamic objects is the Collaborative Perception Service (CPS) which provides information related to perceived non-connected dynamic objects. This concept is based on the dissemination of information, from enabled cooperative vehicles/RSUs, collected by their autonomous perception systems related to non-connected dynamic objects.

In some special cases, the DENS and VBS can also be used to signal the presence of non-connected mobile objects.

5.3.2 Perception of a non-connected vehicle at an intersection use case

5.3.2.1 High level description

The release 2 cooperative vehicle No. 1 is approaching an intersection without having the capability to perceive the arrival of non-connected vehicle(s) on its right before engaging on the intersection. The main ITS Service category is then the "user road safety" which can be achieved by increasing the perception capabilities of the release 2 cooperative vehicle No. 1 using CCAM Augmented Perception ITS Service.

NOTE: The RSU may also notify that there are no vehicle approaching and then that the subject vehicle may going-on without safety risk.

Figure 17 shows a situation illustrating the perception of a non-connected vehicle at an intersection use case.

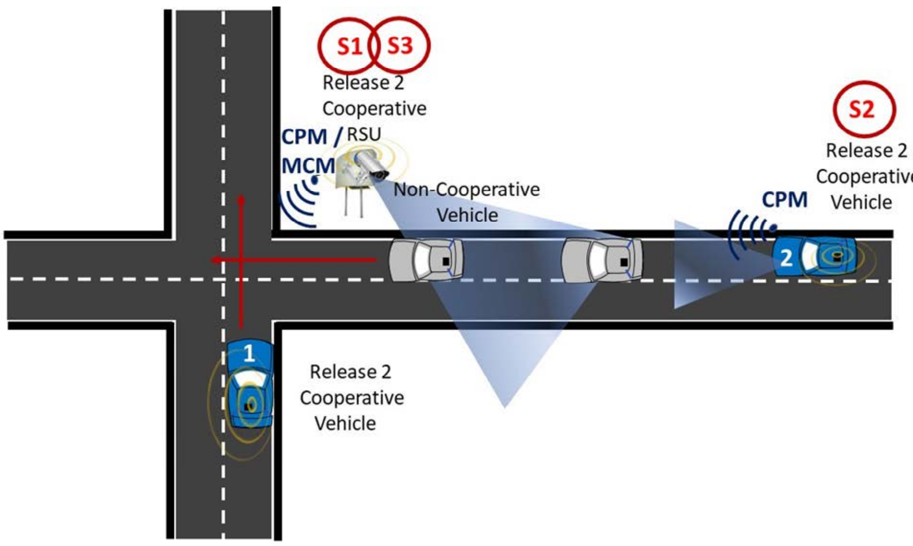


Figure 17: CCAM Augmented Perception at an intersection, use case illustration

5.3.2.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- CPS provided by the vehicle 2 broadcasting CPMs.
- CPS provided by the RSU broadcasting CPMs.
- MCS provided by the RSU broadcasting MCMs.

5.3.2.3 Possible implementation scenarios

S2: Vehicle 2 broadcasts CPMs:

Cooperative blue vehicle No. 2 perceives 2 non-connected vehicles ahead of it. It signals their presence by broadcasting CPMs.

Cooperative blue vehicle No. 1 receives the CPMs broadcasted by cooperative vehicle No. 2 and then act according to its new augmented perception (slowing down) to give priority to the right.

S1: RSU broadcasts CPMs:

Cooperative RSU perceives the 2 non-connected vehicles ahead of cooperative vehicle No. 2 and signals them by broadcasting CPMs.

Cooperative blue vehicle No. 1 receives the CPMs broadcasted by cooperative RSU and then act according to its new augmented perception (slowing down) to give priority to the right.

S3: RSU broadcasts MCMs:

Cooperative RSU broadcast MCMs to ease the cooperative vehicle No. 1 to cross the intersection with the assistance of the cooperative vehicle No. 2.

5.3.2.4 Implementation scenario flow diagram

The flow diagram Model 4, in figure 11 is applicable to this use case.

5.3.2.5 Possible implementation scenarios options

In case of the third implementation scenario (S3), the Agreement Seeking concept is used by the RSU which provides a MC Offer to both cooperative vehicles. Once accepted, the RSU leaves the two non-connected vehicles crossing the intersection and then asks the cooperative vehicle No. 2 to release its right of way to cooperative vehicle No. 1 which may safely cross the intersection.

5.3.3 Perception of a non-connected stationary vehicle at the high of a slop use case

5.3.3.1 High level description

The release 1 or 2 cooperative vehicle (blue one) is approaching the top of a slop without having the capability to perceive the traffic situation on the other side of the slop (when the road goes down). The main ITS Service category is then the "user road safety" which can be achieved by increasing the perception capabilities of the release 1 or 2 cooperative vehicle using CCAM Augmented Perception ITS Service.

Figure 18 shows a situation illustrating the perception of a non-connected stationary vehicle at the high of a top use case.

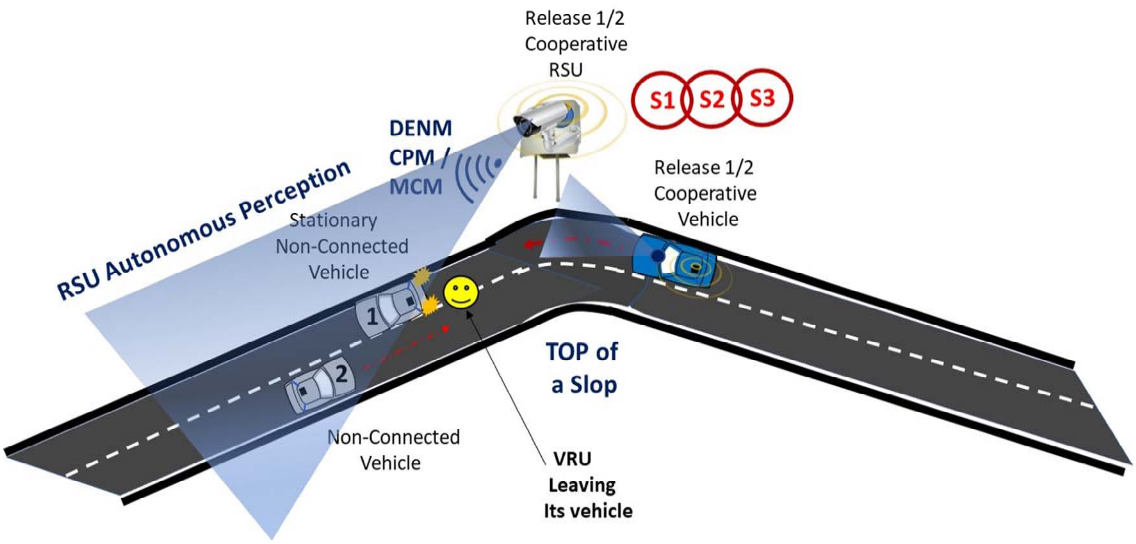


Figure 18: CCAM Augmented Perception at the top of a slop, use case illustration

5.3.3.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the most appropriate one for this use case:

- I2V Cooperation.

Possible ITS-S Services:

- DEN S provided by the RSU broadcasting DENMs for release 1 cooperative vehicles.
- CPS provided by the RSU broadcasting CPMs for release 2 cooperative vehicles.
- MCS provided by the RSU broadcasting MCMs for release 2 cooperative vehicles.

5.3.3.3 Possible implementation scenarios

S1: RSU broadcasts DENMs to release 1 cooperative vehicles:

RSU broadcasts DENMs (stationary vehicle, VRUs on the road) when perceived by its autonomous perception system (camera).

Release 1 cooperative vehicle(s) receive DENMs and slows down to avoid a collision with the stationary vehicle and VRU.

S2: RSU broadcasts CPMs:

RSU broadcasts CPMs signalling the presence of a stationary non-connected vehicle, and of a VRU on the road and the arrival of another non-connected vehicle in the opposite lane.

Release 2 cooperative vehicle upon reception of CPMs slows down and stops behind the stationary vehicle waiting non-connected vehicle 2 to pass before overtaking the stationary vehicle.

5.3.3.4 Implementation scenario flow diagram

RSU broadcasts MCMs requesting release 2 cooperative vehicle(s) to slows down and stops because the presence of a stationary vehicle. Once the opposite lane is detected as free, the RSU proposes waiting release 2 cooperative vehicle(s) to overtake the stationary vehicle.

The following flow diagram (figure 19) illustrates described ITS implementation scenarios.

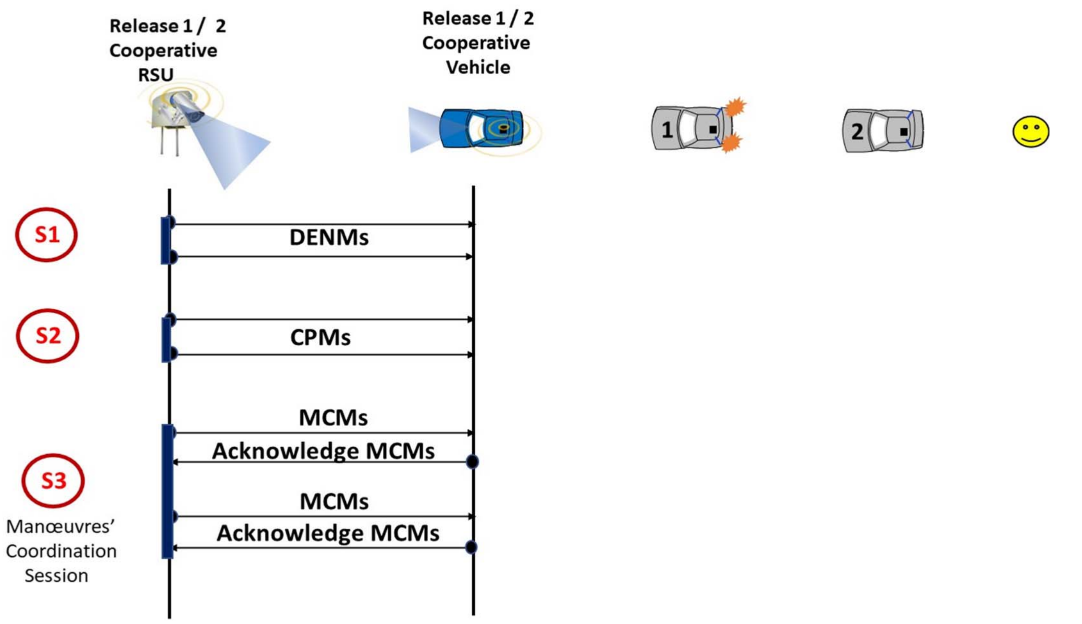


Figure 19: Flow diagram Model 7 using DENMs broadcasting, or CPMs broadcasting and possibly MCMs broadcasting

5.3.3.5 Possible implementation scenarios options

In this use case, the arrival of a non-connected vehicle (No. 2) imposes the RSU to use the prescriptive concept when broadcasting MCMs for avoiding a collision between the cooperative vehicle and the stationary one and the VRU on the road. However, if the opposite lane is free of traffic or if the non-connected vehicle No. 2 is replaced by a release 2 cooperative vehicle, the RSU may propose an agreement seeking concept for the direct overtaking of the stationary vehicle.

5.3.4 Advanced non-connected slow vehicle warning use case

5.3.4.1 High level description

The release 2 cooperative vehicle cannot perceive neither the approaching non-connected slow vehicle nor the non-connected moving one in the opposite direction. The main service category is then the "user road safety" avoiding a collision of the cooperative vehicle with one of the two non-connected vehicles. This can be achieved either by increasing the perception of the cooperative vehicle via the CPS or by guiding the cooperative vehicle to overtake the slow vehicle using the MCS.

Figure 20 shows a situation illustrating the Advanced non-connected slow vehicle warning use case.

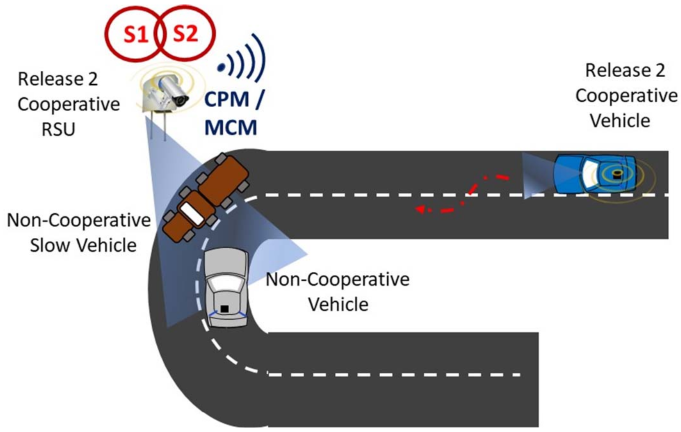


Figure 20: CCAM Augmented Perception of a slow vehicle

5.3.4.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the most appropriate one for this use case:

- I2V cooperation.

Possible ITS-S Services:

- CPS provided by the RSU broadcasting CPMs for release 2 cooperative vehicles.
- MCS provided by the RSU broadcasting MCMs for release 2 cooperative vehicles.

5.3.4.3 Possible implementation scenarios

S1: RSU broadcasts CPMs:

RSU broadcasts CPMs signalling the perception of two non-connected vehicles including a slow vehicle.

Release 2 cooperative vehicle receives the broadcasted CPMs and slows down waiting behind the slow vehicle to achieve its overtaking in safe conditions.

S2: RSU broadcasts MCMs:

RSU broadcast MCMs proposing the best trajectory to cooperative vehicle according to its local traffic perception.

Release 2 cooperative vehicle accepts the manoeuvre coordination and acts according to RSU proposal.

5.3.4.4 Implementation scenario flow diagram

The flow diagram Model 4, in figure 11 is applicable to this use case.

5.3.4.5 Possible implementation scenarios options

MCS Option 1: The cooperative vehicle is in an automated mode:

The RSU makes an offer to coordinate its manoeuvre. The cooperative vehicle accepts the offer and achieves the trajectory proposed by the RSU.

MCS Option 2: The cooperative vehicle is in a human driven mode:

To secure the manoeuvre, the RSU requests a transfer of the vehicle control from human to automated. Then the RSU makes an offer to coordinate the cooperative vehicle manoeuvre. The offer is accepted, and the cooperative vehicle achieved the trajectory proposed by the RSU.

Then the control of the vehicle can be given back to the human driver once the manoeuvre coordination is finished.

5.3.5 V2V/I2V non-connected VRU perception use case

5.3.5.1 High level description

The Subject Vehicle (SV) cannot perceive the Vulnerable Road User which starts crossing the road. The main service category is "user road safety". This is achieved by augmenting the SV perception using CPS or offering its manoeuvre coordination using MCS. The augmented perception can be achieved by both the Target Vehicle (TV) or the RSU. The manoeuvre coordination can only be achieved by the RSU.

Figure 21 shows a situation illustrating the V2V /I2V non-connected VRU perception use case.

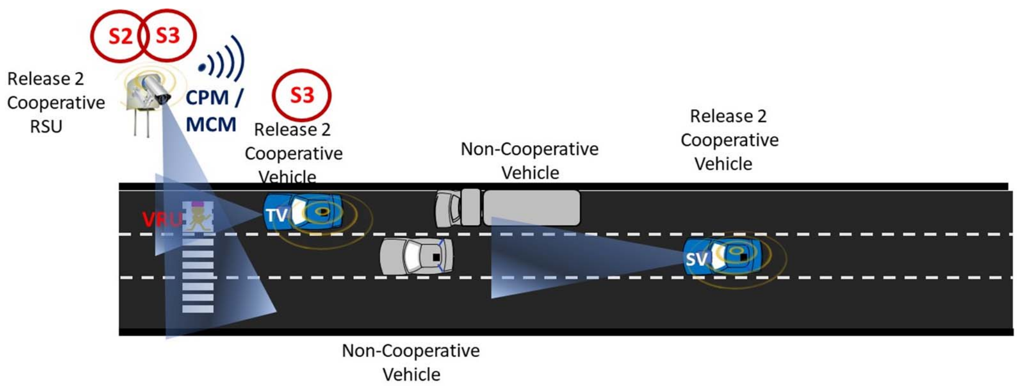


Figure 21: CCAM Augmented Perception of a non-connected VRU

5.3.5.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- CPS provided by the vehicle TV broadcasting CPMs.
- CPS provided by the RSU broadcasting CPMs.
- MCS provided by the RSU broadcasting MCMs.

5.3.5.3 Possible implementation scenarios

S1: Target release 2 cooperative vehicle (TV) broadcasts CPMs:

TV cooperative vehicle detects the VRU crossing the road with its front camera and then broadcasts CPMs signalling its presence on the pedestrian crossing.

SV cooperative vehicle receives the broadcasted CPMs and slows down to stop at the pedestrian crossing level as long as the VRU has not reached the opposite side of the road.

S2: RSU broadcasts CPMs:

Cooperative RSU perceived the VRU crossing the road and then broadcasts CPMs signalling him.

SV cooperative vehicle receives the broadcasted CPMs from the RSU and then slows down and stops if necessary to avoid a collision with the VRU.

S3: RSU broadcasts MCMs:

Cooperative RSU broadcast MCMs to offer a manoeuvre coordination to approaching release 2 cooperative vehicles protecting the crossing VRU.

Subject(s) cooperative vehicle(s) accept the RSU offer and then act accordingly to proposed trajectories.

5.3.5.4 Implementation scenario flow diagram

The flow diagram Model 4, in figure 11 is applicable to this use case.

5.3.5.5 Possible implementation scenarios options

MCS Option 1: The cooperative vehicle is in an automated driving mode:

The RSU makes an offer to coordinate its manoeuvre. The cooperative vehicle accepts the offer and achieves the trajectory proposed by the RSU.

MCS Option 2: The cooperative vehicle is in a human driven mode and the TTC is low (e.g.: < 1 second):

The RSU sends an emergency brake to the cooperative subject vehicle which automatically activates its secondary braking system.

5.3.6 Perception into a tunnel use case

5.3.6.1 High level description

An automated vehicle is approaching a tunnel entry without having the capability to adequately perceive all other road users beyond the tunnel entry (due to sensor degradation). The main ITS Service category is then the "user road safety" which can be achieved by increasing the perception capabilities of the approaching automated vehicle using CCAM Augmented Perception ITS Service.

5.3.6.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation,
- I2V Cooperation.

Possible ITS-S Services:

- CPS provided by the RSU broadcasting CPMs.
- CPS provided by a cooperative vehicle within the tunnel broadcasting CPMs.

5.3.6.3 Possible implementation scenarios

S1: RSU broadcasts CPMs:

Cooperative RSU perceives all vehicles at the tunnel entry and signals them by broadcasting CPMs.

Approaching cooperative vehicle receives the CPMs broadcasted by cooperative RSU and then acts according to its new augmented perception to safely enter the tunnel.

S2: Vehicle within the tunnel broadcasts CPMs:

Cooperative vehicle within the tunnel perceives non-connected (or not-cooperative) vehicles in its vicinity. It signals their presence by broadcasting CPMs.

Approaching cooperative vehicle receives the CPMs broadcasted by cooperative vehicle within the tunnel and then acts according to its new augmented perception to safely enter the tunnel.

5.3.6.4 Implementation scenario flow diagram

The flow diagram Model 4, in figure 11 (without MCMs) is applicable to this use case.

5.3.6.5 Possible implementation scenarios options

The receiving vehicle acts according to its new augmented perception to safely enter the tunnel and/or slows down or stops according to the traffic situation.

5.3.7 Perception of traffic when merging use case

5.3.7.1 High level description

An automated vehicle is approaching a road merge without having the capability to adequately perceive all other road users approaching on the main road (due to occlusion). The main ITS Service category is then the "user road safety" which can be achieved by increasing the perception capabilities of the approaching automated vehicle using CCAM Augmented Perception ITS Service.

5.3.7.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- CPS provided by the RSU broadcasting CPMs.
- CPS provided by a cooperative vehicle approaching on the main road broadcasting CPMs.

5.3.7.3 Possible implementation scenarios

S1: RSU broadcasts CPMs:

Cooperative RSU perceives all vehicles at the road merge and signals them by broadcasting CPMs.

Merging cooperative vehicle receives the CPMs broadcasted by cooperative RSU and then acts according to its new augmented perception to safely merge onto the main road.

S2: Vehicle approaching the road merge broadcasts CPMs:

Cooperative vehicle approaching the road merge on the main road perceives non-connected vehicles in its vicinity. It signals their presence by broadcasting CPMs.

Merging cooperative vehicle receives the CPMs broadcasted by cooperative vehicle approaching the road merge on the main road and then acts according to its new augmented perception to safely merge onto the main road.

5.3.7.4 Implementation scenario flow diagram

The flow diagram Model 4, in figure 11 (without MCMs) is applicable to this use case.

5.3.7.5 Possible implementation scenarios options

The receiving vehicle acts according to its new augmented perception to safely merge and/or slows down or stops according to the traffic situation.

5.4 Vehicles' coordination

5.4.1 ITS service introduction

Under this ITS service fall ITS applications that use ITS-S services to coordinate vehicle movements in terms of manoeuvres or trajectories. As the capability to plan possible future manoeuvres and trajectories is a prerogative of vehicles with higher automation levels (L3+), this ITS service is targeted at those vehicles. Several forms of coordination with different complexity are possible. For example, messages can be exchanged to allow vehicles follow, at a safe distance, the trajectory of other vehicles in front (follow-me). Alternatively, vehicles can exchange messages to notify the intention to implement specific manoeuvre, enable cooperative manoeuvre as well as to acknowledge whether manoeuvre intentions of other vehicles can be safely implemented. Coordination can run between vehicles or with the support of the road infrastructure or a central supervision system. In this last case, roadside or central ITS-Ss might suggest vehicles to implement specific manoeuvres that in turn vehicles could decide to accept or not based for example on own safety constraints in the current driving environment. The manoeuvre suggestions could be common to several vehicles or specifically addressed to individual vehicles. In any case, the expected impact of this ITS Service is to increase traffic safety and efficiency at the same time thanks to an explicit coordination of actions between cooperative highly automated vehicles. Knowing about each other "plans" would allow receiving vehicles to know in advance how to react (e.g. safely slows down when a vehicle ahead notifies the intention to merge on the ego-lane), but also to keep less conservative time gaps from the surrounding cooperative vehicles.

5.4.2 Cooperative Lane Merging (CLM) use case

5.4.2.1 High level description

When two lanes are merging, cooperative vehicles approaching the merging point have to agree to synchronize their manoeuvres especially in case of a high traffic density. This is illustrated on the proposed use case at the level of a highway when a release 2 cooperative vehicle arriving on the access lane of the highway has to insert on the right lane of the highway without having the right of way. Thanks to the new MCS, release 2 cooperative vehicles may coordinate their manoeuvre (V2V) or can be assisted by a local release 2 cooperative RSU which may act as a "virtual traffic agent" to coordinate manoeuvre of release 2 cooperative vehicles accessing to the highway.

NOTE: This use case is also relevant at the level of a roundabout where lane merging or lane change can be frequent.

Figure 22 shows a situation illustrating the cooperative lane merging use case.

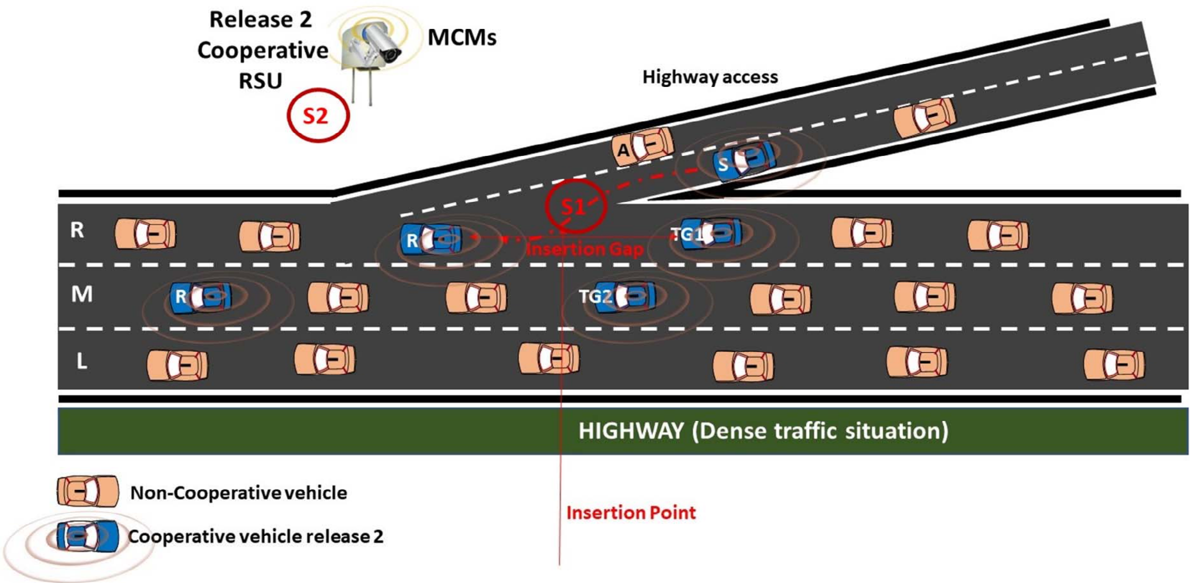


Figure 22: Cooperative Lane Merging use case illustration

5.4.2.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- V2V MCS cooperation.
- I2V MCS cooperation.

5.4.2.3 Possible implementation scenarios

S1: V2V MCS Cooperation:

When a release 2 cooperative subject vehicle (S) is approaching the merging area of the highway access lane with the highway right lane, this one may start a manoeuvre coordination session with other relevant release 2 cooperative vehicles (Target 1 (TG1) and Target 2 (TG2)). The TG1 vehicle is requested to adjust its trajectory to create an insertion gap for the subject vehicle, while the TG2 vehicle is requested to remain in its lane during the subject vehicle insertion. Then, the subject vehicle may safely insert between relevant vehicle being ahead (R) and the TG1 vehicles.

S2: I2V MCS Cooperation:

The release 2 cooperative RSU perceives the subject vehicle insertion problem and may offer it an assistance for its safe insertion on the highway right lane. If agreed, the RSU coordinates the manoeuvre of the TG1 and TG2 to facilitate the opening of a safe insertion gap for the subject vehicle.

5.4.2.4 Implementation scenario flow diagram

The following flow diagram (figure 23) illustrates described ITS implementation scenarios.

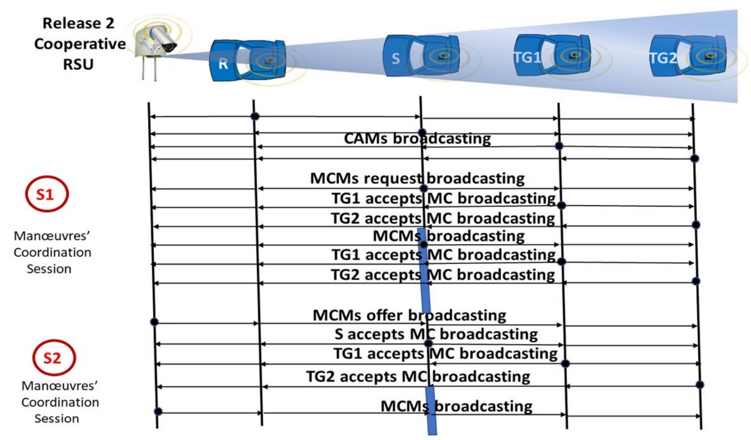


Figure 23: Flow diagram Model 8, focusing on MCMs broadcasting

5.4.2.5 Possible implementation scenarios options

Scenario 1: The Agreement Seeking MC concept can be used by the subject vehicle to request a manoeuvre coordination cooperation. In this case, the subject vehicle may provide its new reference trajectory or may provide the proposed reference trajectories to TG1 (slowdown) and TG2 (keep lane).

Scenario 2: The Agreement seeking MC concept may also be used by the release 2 cooperative RSU which may propose new reference trajectories to TG1 (slowdown) and TG2 (keep lane).

5.4.3 Cooperative Lane Change (CLC) use case

5.4.3.1 High level description

Lane changes are very frequent and present a diversity of situations (e.g. overtaking vehicles, exiting a road, crossing a highway toll collect, etc.) which may require a succession of manoeuvre coordination.

The overtaking of vehicles can be a complex lane change when the traffic density is high.

Figure 24 shows a situation illustrating the cooperative lane change use case.

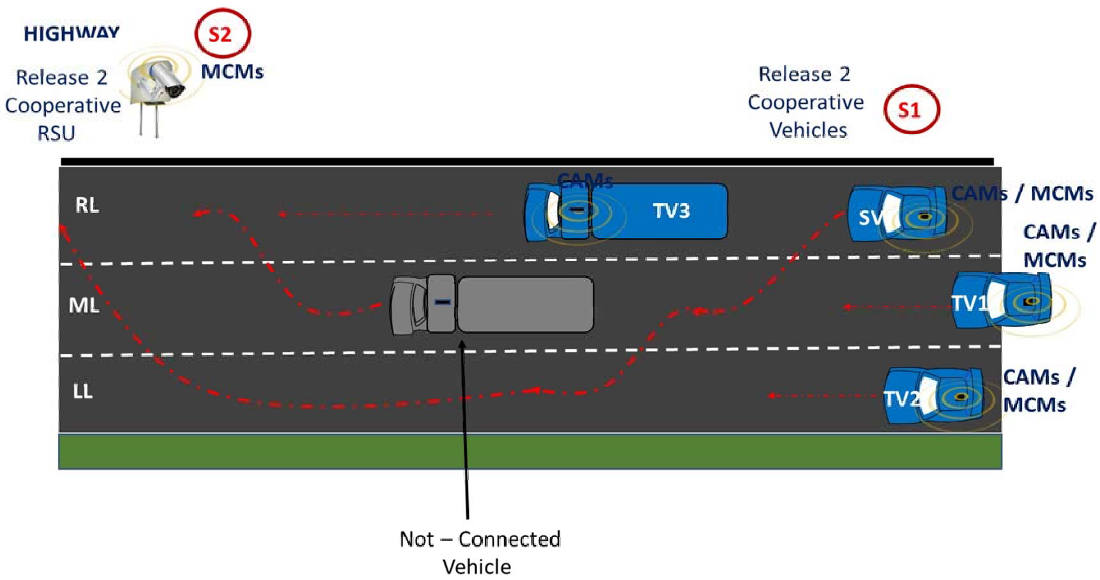


Figure 24: Cooperative Lane Change use case illustration

5.4.3.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- V2V MCS cooperation.
- I2V MCS cooperation.

5.4.3.3 Possible implementation scenarios

S1: V2V MCS Cooperation:

The 4 release 2 cooperative vehicles (SV, TV1, TV2, TV3, etc.) cooperate via the coordination of their manoeuvres to assist the subject vehicle successfully and safely overtaking the two trucks. At least the 3 following Manoeuvre coordination sessions are necessary:

- Lane change from the Right Lane (RL) to the Middle Lane (ML).
- Lane change from ML to Left Lane (LL).
- Then lane change from LL to RL.

S2: I2V MCS Cooperation:

The release 2 cooperative RSU offers to coordinate the manoeuvre of SV for it to be able overtaking successfully and safely the two trucks. The MC process can be like the one of S1.

5.4.3.4 Implementation scenario flow diagram

The flow diagram Model 8, in figure 23 is applicable to this use case.

5.4.3.5 Possible implementation scenarios options

Both scenarios require the addition of safety containers in CAMs.

5.4.4 Advanced Cooperative ACC (String) (AC-ACC S) use case

5.4.4.1 High level description

This use case is based on the use of V2X to obtain lead vehicle dynamics and general traffic ahead to enhance the performances of ACC and ACC string as defined in clause 5.2.4. Compared to the normal C-ACC it includes support for lateral vehicle control in addition to longitudinal one. Therefore, it will require usage of safety containers guaranteeing higher information quality. In case of a string of ACC vehicles, the control of the string is decentralized and differently from Platooning does not require a dedicated platoon control message. The infrastructure can play a similar role as for C-ACC and C-ACC-S using IVIM extensions. In this case IVIMs can additionally suggest lane changes. As this use case might be run by vehicles with high automation level, IVIMs are expected to be as well complemented by safety containers (for functional safety reasons).

5.4.4.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- V2V CAS including safety containers.
- I2V IVI including safety containers.

5.4.4.3 Possible implementation scenarios

S1: V2V using CAMs with safety containers:

One possible implementation scenario is to use V2V communication only. At least one vehicle B follows a lead vehicle A. Vehicle B actuates both its longitudinal and lateral control based on the information received from vehicle A's dynamics via CAMs and/or CPMs.

S2: I2V using IVIMs with safety containers:

A second implementation scenario is the additional inclusion of I2V communication. In this scenario, the actuation of longitudinal and lateral control of both the leading and following vehicle takes information and recommendations received through IVIM by the infrastructure into account.

5.4.4.4 Possible implementation scenarios options

Both scenarios require the addition of safety containers in CAMs/IVIMs.

5.4.5 Truck platooning management use case

5.4.5.1 High level description

Platooning and Cooperative Adaptive Cruise Control (C-ACC) are enabled by adding wireless communication to already automated functionalities such as longitudinal and lateral control of the vehicle. Vehicles' string including platooning encompasses both lateral as well as longitudinal control of the vehicle, whereas C-ACC usually addresses only longitudinal (brake and acceleration).

At the level of longitudinal control, C-ACC (Cooperative - Active Cruise Control) development has enabled the possibility to reduce the minimum inter-distance between vehicles to a few meters (6 to 10 meters). Such function enables the building of truck platoons (a maximum of 4 vehicles seems acceptable) which are moving in synchronization. The small gap of 6 to 10 meters between them does not allow an easy safe insertion of another vehicle. Consequently, in some situation, a platoon may need to be broken (e.g. before reaching a motorway exit in dense traffic situation) to leave other vehicles to change of lane and leave the motorway. Some other situations may also need the support of the road infrastructure, for example when two motorways are joining, for maintaining as far as possible an existing platoon.

5.4.5.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- V2V MCS extension.
- I2V IVI Service.

5.4.5.3 Possible implementation scenarios

S1: V2V using MCMs:

Truck platoons are vehicles moving in synchronization with a truck leader. Once a truck platoon is formed, the leader needs just to broadcast its reference trajectories and then other cooperative vehicles which constitute the platoon have to follow the same reference trajectory according to safety rules (e.g. minimum inter-vehicles time distance) which have been set at platoon formation time. MCMs can be used for managing the platoon states:

- Activate/Deactivate a platoon.
- Join to/merge with a platoon.
- Maintain a platoon.
- Leave/Dissolve a platoon.

S2: I2V using IVIMs:

The IVIM standard includes already a container dedicated to platooning rules. Consequently, a consistent approach with this standard is needed.

5.4.6 Toll Plaza Guidance use case

5.4.6.1 High level description

For partly and fully automated vehicles, toll plazas are obstacles on the road where additional information directly sent from infrastructure can assist them to safely pass through. Example for this information contains:

- Available lanes per direction including certain restriction i.e. for buses or trucks.

- Payment methods per lane (i.e. free flow for automated vehicles).
- Lane utilization so vehicles can choose the quickest path.
- Relevance areas in advance to the toll plaza if partly automated vehicles need to hand over control to the driver.
- Status of gates, barriers, or traffic lights to drive through the toll plaza.

With the information, automated vehicles can choose the correct lanes and drive through the toll plaza without assistance of the driver or passenger.

5.4.6.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the most appropriate one for this use case:

- I2V Cooperation.

Possible ITS-S Services:

- I2V IVI, MAPEM, SPAT Service.

5.4.6.3 Possible implementation scenarios

S1: I2V using IVI, SPAT and MAPEM:

Using the IVI, SPAT and MAPEM, the necessary information (GNSS-Information, lane status and utilization, payment methods, traffic light status, etc.) will be transmitted.

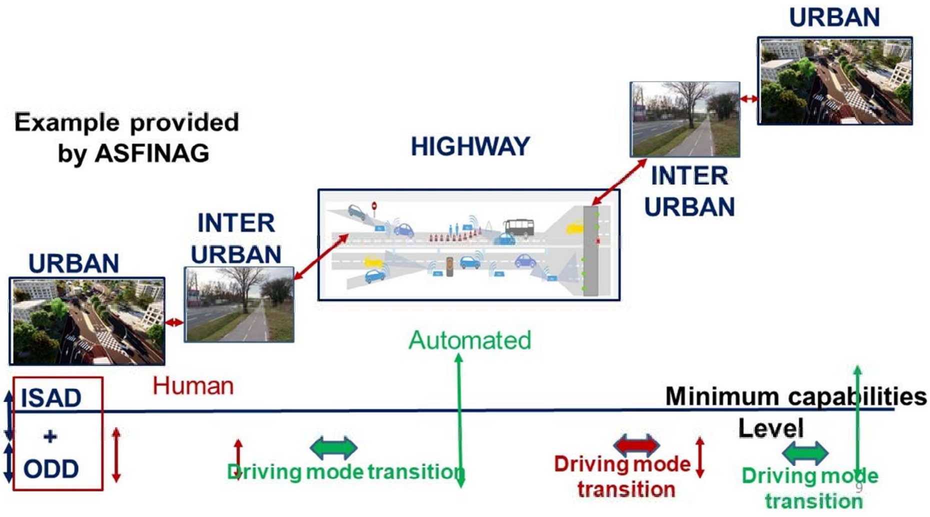
5.4.7 Cooperative transition control use case

5.4.7.1 High level description

For highly automated vehicles (L3+) a Transfer of Control (ToC) is the process by which, driving and monitoring tasks are handled over from the automated system to the human driver or vice versa.

For the transfer from automated to human driven, it has been demonstrated by several studies that, depending on the level of attention of the driver, the first instants after the takeover might be critical and lead to an erratic driving behaviour, which in turn can be a risk for surrounding traffic. This phenomenon can imply even bigger risks at the so called "transition areas" where, due to multiple possible reasons (e.g. ODD violation), a big number of automated vehicles might want to give back control to their drivers in the same place at the same time. If takeovers fail at one or multiple vehicles, additional risks, and inefficiencies (e.g. accidents or traffic jams) can be caused by Minimum Risky Manoeuvres (MRM). To mitigate the possible negative effects of transition of ToCs and MRMs, cooperative transfer of control ITS applications can be implemented. Vehicles can inform each other in a distributed way about imminent transfer of control and minimum risky manoeuvres. Similarly, the road infrastructure can anticipate simultaneous occurrence of transfers of control in the same location and suggest incoming vehicles to trigger their transfer at distinct points and times, in such a way not to concentrate them in the same area.

Figure 25 shows a situation illustrating the cooperative transition control use case.



The driving mode transition is conditionned by the respective capabilities of the vehicle and the road infrastructure (ISA + ODD).

Figure 25: Example of Driving Mode Transition use case

5.4.7.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- V2V MCS.
- I2V MCS.

5.4.7.3 Possible implementation scenarios

S1: V2V using MCMs:

The MCM contains one vehicle automation level container which indicates what is the current vehicle automation level (from SAE level 0 to SAE level 5).

This container can also be used to indicate a change of driving mode (two successive MCMs presenting a different level of automation). Such transition information can be used to avoid several other simultaneous transitions.

A subject vehicle may also request via MCMs target vehicles to change their driving modes (e.g. from human to automated) to ease their trajectories adaptations.

S2: I2V using MCMs:

The loss of some road infrastructure ODD capabilities can be leading an RSU to request a driving mode change for cooperative vehicles which do not have the capability to stay autonomous without the support of the road infrastructure (e.g. ToC from automated to human driven). In opposite, the restitution of a road infrastructure full ODD capabilities can lead an RSU to propose a driving mode change from human driven to automated.

The RSU may avoid a simultaneous ToC for cooperative vehicles transiting from automated to human driven. This can be achieved by starting the ToC before the complete loss of related road infrastructure ODD capabilities.

5.4.7.4 Implementation scenario flow diagram

The flow diagram Model 8, in figure 23 is applicable to this use case.

5.5 Multi-Car Collision avoidance

5.5.1 ITS service introduction

The collision avoidance (crash avoidance) service is constituted of a functional ITS applications pipeline which is illustrated in figure 26.

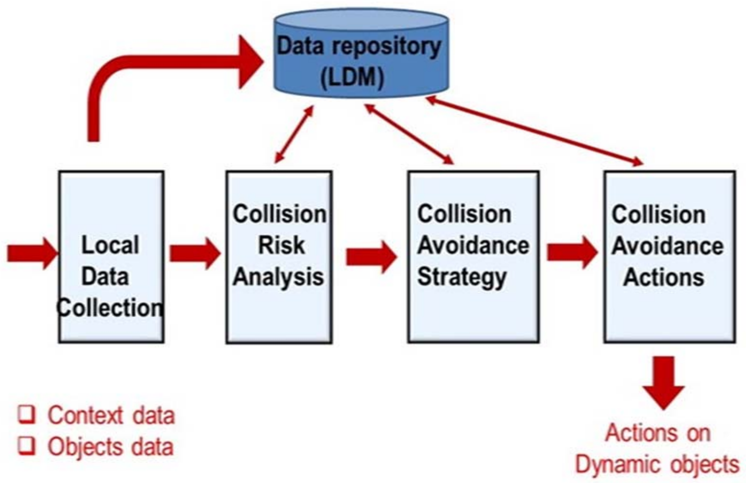


Figure 26: Functional pipeline illustrating the collision avoidance ITS service

With the navigation ITS service it is one essential generic ITS service which is mandatory at the level of vehicles moving in a partial or full automated mode. Mixed traffic situations mixing-up human driven vehicles with partly and fully automated vehicles constitute a huge challenge to the collision avoidance application.

Collision avoidance use cases are added in the present document. They are far from being exhaustive as many different collision risk situations may be observed.

A Multi-Car collision implies that at least two vehicles are involved in the collision, however, in many cases more than two vehicles can be involved.

Artificial Intelligence (AI) can be used at the level of the collision risk analysis function. However, the quantity of data to be locally collected is considerable and includes the contextual data (traffic situation, road topography, horizontal marking and vertical signalling, weather conditions, human behaviours, etc.). The complexity and diversity of situations will require an intensive use of simulations (machine learning) to develop and validate efficient algorithms for risk analysis and collision avoidance.

5.5.2 Advanced signal violation warning use case

5.5.2.1 High level description

One not - connected vehicle is violating a traffic light red signal. This can be detected and signalled by the release 2 Target cooperative Vehicle (TV) and the release 2 cooperative RSU.

The release 1 subject cooperative vehicle (green SV2) may only process DENMs while the release 2 Subject cooperative Vehicle (blue SV1) may also process CPMs and MCMs.

Figure 27 shows a situation illustrating the advanced signal violation warning use case.

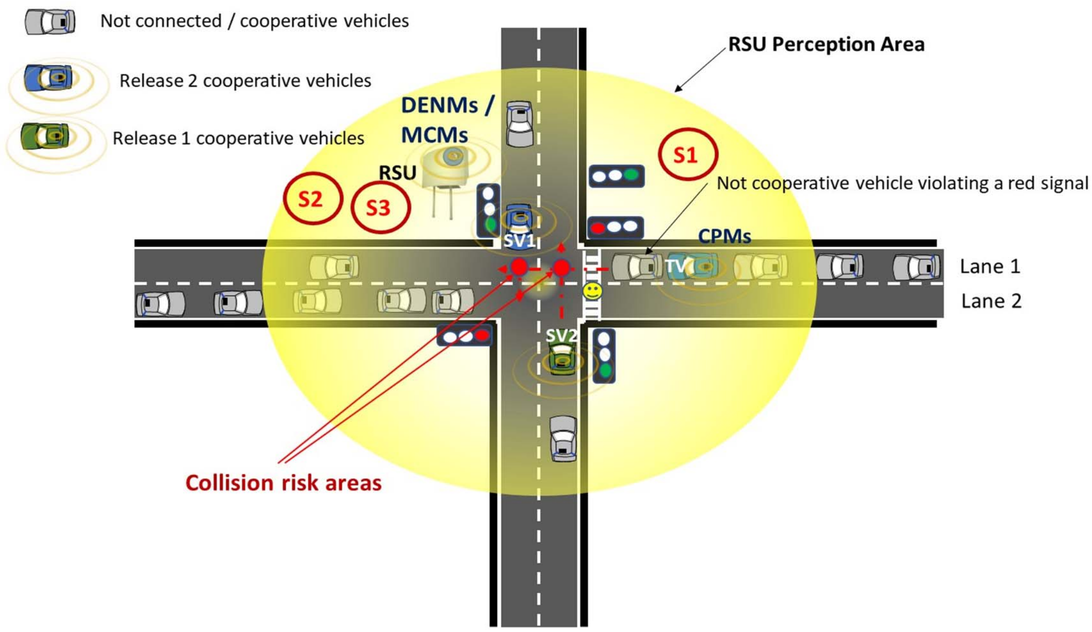


Figure 27: Advanced signal violation use case

5.5.2.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the be most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- V2V SPAT and CPMs.
- I2V DENMs/MCMs.

5.5.2.3 Possible implementation scenarios

S1: V2V using SPAT and CPMs:

In this scenario, the release 2 cooperative TV vehicle detects the not-connected vehicle and signals it by broadcasting CPMs.

The release 2 subject cooperative vehicle SV1 receives the CPMs as well as the SPAT & MAP and has then the capability to detect a signal violation by the not-connected vehicle. The SV1 can act to reduce the risk of collision or mitigate its impacts.

S2: I2V using DENMs:

The RSU detects a risk of signal violation between the not-connected vehicle and the cooperative Subject Vehicles (SV1 and SV2). The RSU broadcasts DENMs (signal violation warning) which are received by both vehicles (Release 1 and Release 2) which can act accordingly to avoid or mitigate the risk of collision.

S3: I2V using MCMs:

The RSU detects the risk of collision and proposes to assist release 2 Subject cooperative Vehicle SV1 in collision avoidance with the not-connected vehicle. If accepted, the manoeuvre coordination is controlled by the RSU (via MCMs) which has a full perception of this local environment.

5.5.2.4 Implementation scenario flow diagram

The following flow diagram (figure 28) illustrates described ITS implementation scenarios.

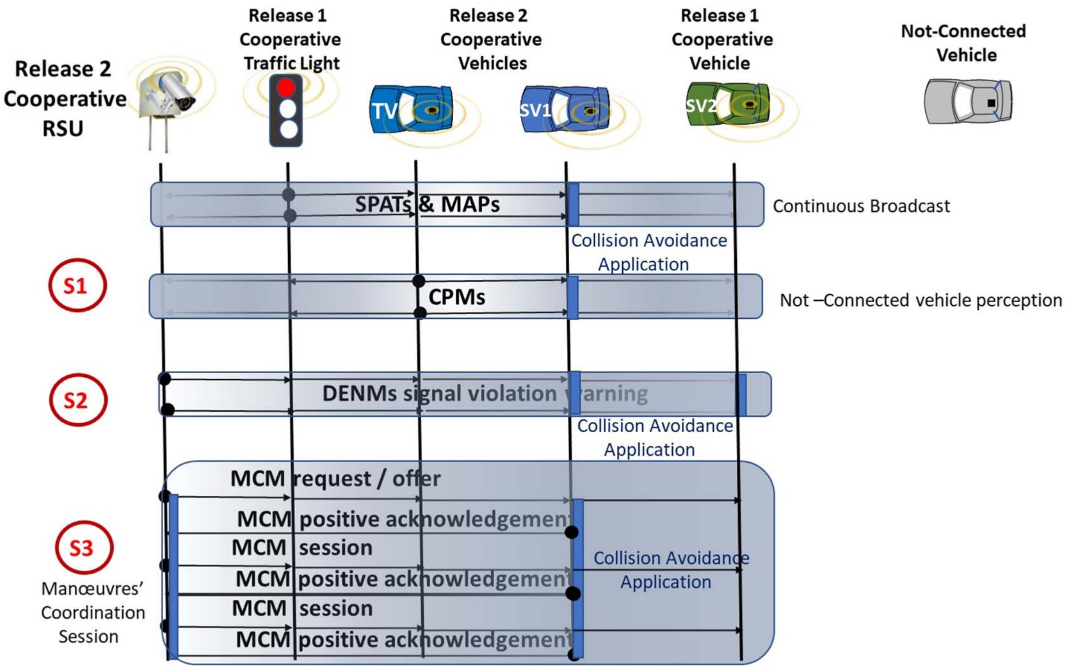


Figure 28: Flow diagram, Model 9 combining SPAT/MAP, CPMs, DENMs and MCMs

5.5.2.5 Possible implementation scenarios options

S1 scenario: Only release 2 cooperative vehicles can benefit of the CPS. The release 1 Subject cooperative Vehicle (SV2) cannot decode the CPMs.

S2 scenario: Both release 1 and release 2 cooperative subject vehicles can decode and use the received DENMs to avoid or mitigate collision.

S3 scenario: The RSU assists release 2 subject cooperative vehicle to avoid or mitigate collision with the not-connected vehicle. The Agreement Seeking concept as well as the Prescription concept can be used according to the choice made by the road authority.

5.5.3 Advanced wrong way driving warning use case

5.5.3.1 High level description

The release 2 cooperative Target Vehicle (TV) is engaging in a wrong way (countersense of the highway exit). In such situation, it is urgent to act to avoid the TV vehicle to continue its wrong trajectory. The Release 2 cooperative RSU is perceiving this situation and then signals it to Release 1 (SV2) and release 2 (SV1) cooperative vehicles trying to prevent collisions.

The urgency is required to avoid that the wrong way driven vehicle may enter the highway, so increasing the risk of frontal collision with vehicles moving on the highway.

Figure 29 shows a situation illustrating the advanced wrong way driving use case.

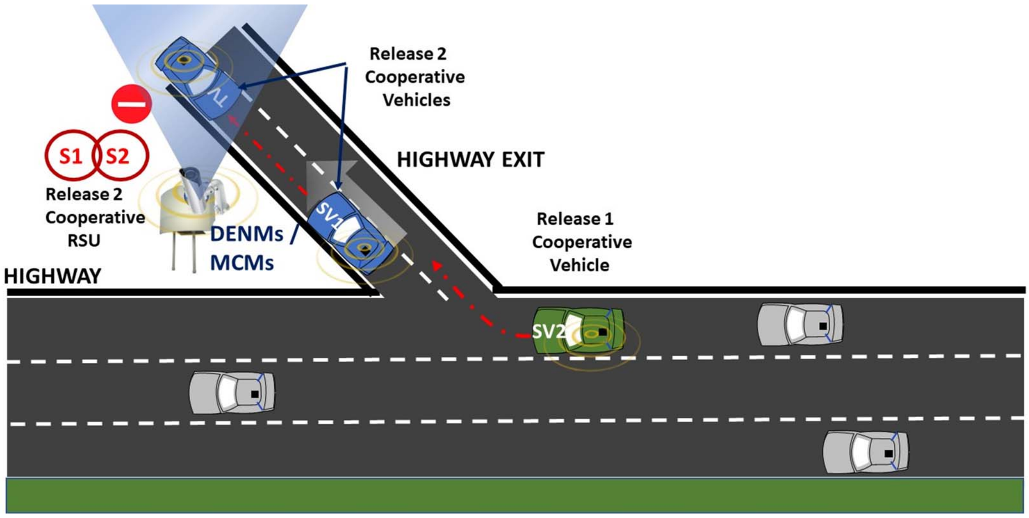


Figure 29: Advanced wrong way driving use case

5.5.3.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the most appropriate one for this use case:

- I2V Cooperation.

Possible ITS-S Services:

- I2V DENMs/MCMs.

5.5.3.3 Possible implementation scenarios

S1: I2V using DENMs:

The release 2 cooperative RSU broadcasts DENMs wrong way driving which are received and decoded by release 1 and release 2 vehicles. These vehicles may then act to reduce or mitigate the risk of collision changing their trajectories or/and slowing down.

S2: I2V using MCMs:

The release 2 cooperative RSU is also offering its assistance to release 2 cooperative vehicles by broadcasting MCMs. If accepted, the RSU may assist the TV to leave its wrong way driving trajectory and assist other release 2 cooperative vehicles to avoid colliding with TV.

5.5.3.4 Implementation scenario flow diagram

The flow diagram Model 1, in figure 3 is applicable to this use case.

5.5.3.5 Possible implementation scenarios options

Scenario 1: DENMs provides only information about risks related to a wrong way driving situation. The correction of this situation and elimination of associated collision risks relies only at the level of each receiving human driven/automated cooperative vehicle.

Scenario 2: The RSU acts directly on release 2 vehicles to avoid collision. The Agreement Seeking concept or the Prescription concept can be used according to local road authority roles and responsibilities.

5.6 Intersection crossing assist

5.6.1 ITS service introduction

Roads' intersections are critical areas in terms of road safety as various types of vehicles are crossing them, often without a total perception. They are also critical areas in terms of traffic management leading to specific traffic regulations and to traffic control using specific means as well to enforce road safety to regulate the local traffic.

5.6.2 Advanced Intersection Collision Warning (AICW) use case

5.6.2.1 High level description

By receiving information about non-cooperative vehicles detected by environmental sensors (CPMs), vehicles can detect the risk of an intersection collision and warn the driver accordingly.

5.6.2.2 Possible ITS architecture and ITS-S services

Architecture A: Cooperative vehicles and road-side infrastructure provide information on objects detected by their sensors through CPM. Receiving vehicles make use of this information in addition to the received CAMs to issue an intersection collision warning if appropriate.

5.6.2.3 Possible implementation scenarios options

Implementation A: This implementation option refers to Architecture A. In addition to the dynamics information in CAMs, vehicles can make use of object information received from other vehicles or infrastructure to activate the intersection collision warning. Thus, also warnings about collision risks with non-cooperative vehicles can be issued and thus safety is fostered even more.

5.6.3 Not controlled intersection use case

5.6.3.1 High level description

At the level of a not-controlled intersection, the right of way is for the vehicles which are arriving from the right. This means that the two release 2 cooperative Subject Vehicles (SV) do not have the right of way over the release 2 cooperative Target Vehicle (TV). However, this TV vehicle may offer to transfer its right of way to the two subject vehicles or the release 2 cooperative RSU may request the target vehicle to do it.

This can be achieved to optimize the local traffic management while ensuring the road safety.

Figure 30 shows a situation illustrating the not controlled intersection use case.

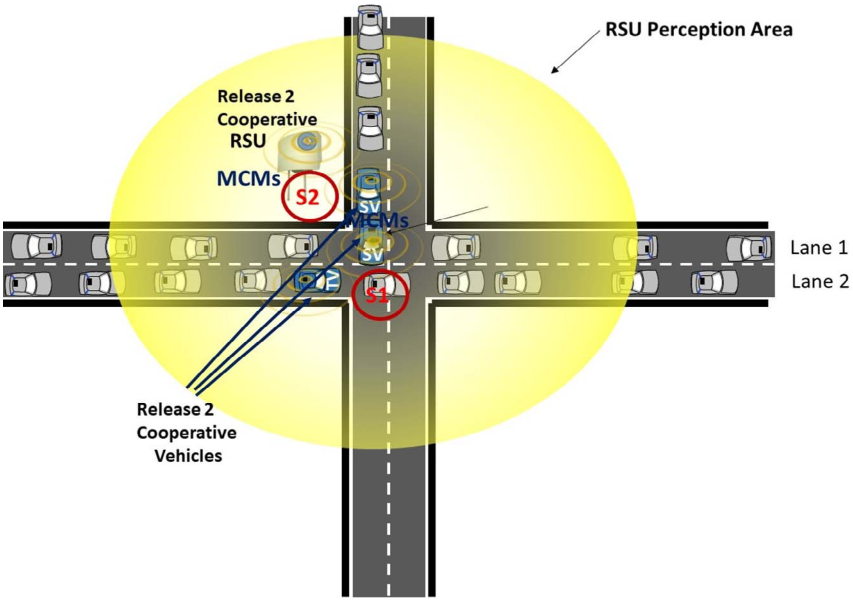


Figure 30: Not controlled intersection crossing assistance use case

5.6.3.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- MCS.

5.6.3.3 Possible implementation scenarios

S1: V2V using MCMs:

The release 2 cooperative Target Vehicle (TV) offers to release its right of way to the two Subject Vehicles (SV) which are approaching the intersection. This is achieved via the broadcasting of MCMs. The two subject vehicles accept the offer and may cross the intersection while TV is waiting them to cross.

S2: I2V using MCMs:

The release 2 cooperative RSU requests TV to stop at the intersection to leave the two release 2 two cooperative vehicle the priority to cross the intersection using MCM. The three cooperative vehicles accept this request, and the two subject vehicles may cross safely the intersection.

5.6.3.4 Implementation scenario flow diagram

The flow diagram Model 1, in figure 3 (without the DENM part) is applicable to this use case.

5.6.3.5 Possible implementation scenarios options

The scenario 1 can use the MC Agreement Seeking concept, while the scenario 2 may use the Prescription concept if judged efficient for local or global traffic regulation.

5.6.4 Traffic light-controlled intersection - Priority vehicles management use case

5.6.4.1 High level description

An active emergency vehicle is approaching at an intersection which is controlled by traffic lights. The subject traffic light is red; however two different traffic scenarios are possible to facilitate the urgent crossing of the emergency vehicle (TV):

- The Subject Traffic Light (STL) transits to green, all others traffic lights transiting or remaining reds. But in this case, this can only be achieved once the crossing VRU has left the pedestrian crossing.
- The emergency vehicle (TV) gets the right of way and then violates the STL red state. But in this case, all vehicles which have the right of way given by a green light have to perceive the arrival of the emergency vehicle and then release it their right of way.

Figure 31 shows a situation illustrating the traffic light-controlled intersection - priority vehicles management use case.

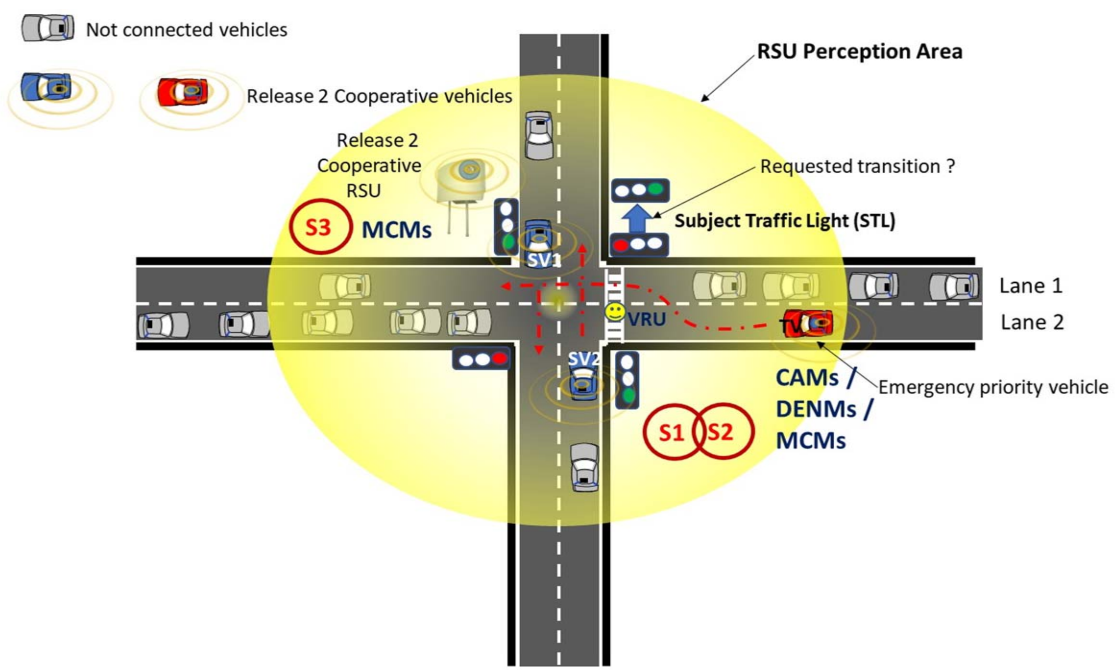


Figure 31: Traffic light-controlled intersection - priority vehicle management use case

5.6.4.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- CAS.
- DEN S.
- MCS.

5.6.4.3 Possible implementation scenarios

S1: V2V using CAMs or/DENMs:

The active emergency vehicle (TV) broadcasts CAMs including the emergency container which indicates that the emergency vehicle is in operation and then got traffic privileges. This could be reinforced by the broadcasting of DENMs indicating an emergency vehicle in approach.

Either the STL remains red, and the emergency vehicle violates the red signal taking care of the crossing VRU, or the STL is switched to green.

Subject vehicles which had the right of way given by a green traffic light have to perceive the arrival of the emergency vehicle and then release their right of way.

S2: V2V using MCMs:

Release 2 cooperative vehicles may use the MCS, broadcasting MCMs to initiate and progress a manoeuvre coordination session. The TV broadcasts an MCM request and other release 2 cooperative subject vehicles (SV1 & SV2) accept the TV proposal leaving the right of way to TV.

S3: I2V using MCMs:

Release 2 cooperative RSU takes the initiative to coordinate the manoeuvre of release 2 relevant cooperative vehicles via an MCM offer or an MCM request.

Relevant vehicles (TV, SV1, SV2) accept the RSU proposal and execute proposed manoeuvre.

5.6.4.4 Implementation scenario flow diagram

The following flow diagram (figure 32) illustrates described ITS implementation scenarios.

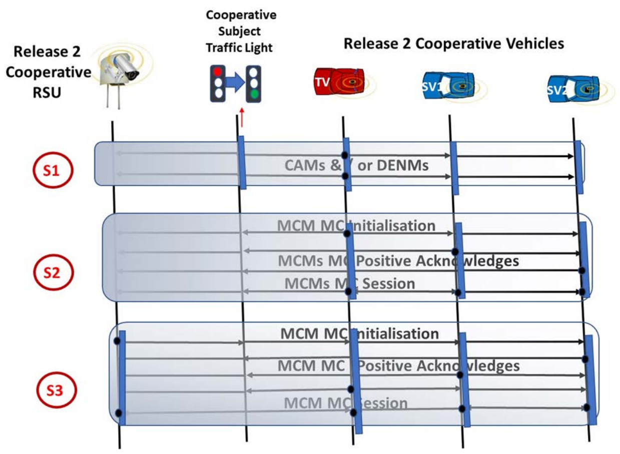


Figure 32: Flow diagram, Model 10 combining CAMs broadcasting, DENMs broadcasting and MCMs broadcasting

5.6.4.5 Possible implementation scenarios options

Scenario 1: CAMs or/and DENMs can be used by receiving ITS-S release 1 or release 2 to act to provide the right of way to emergency vehicle.

Cooperative subject traffic light may decide to switch green or stay red.

Scenario 2: MC concept would be preferably Prescriptive to reinforce the right of way of the emergency vehicle.

Scenario 3: MC concept would be preferably also prescriptive to reinforce the right of way of the priority vehicle.

5.6.5 Optimized traffic light information from V2I use case

5.6.5.1 High level description

In proximity of signalized intersections, cooperative automated vehicle ITS-Ss (isolated or organized in strings (platoons or C-ACC)) continuously transmit information describing their status (e.g. the occurrence of a hazardous event), intentions (e.g. planned route for transiting intersection), targets (e.g. desired speeds), or characteristics (e.g. string size, current automation level, etc.). By collecting this explicit probing V2I information, the intersection control system (e.g. the traffic light controller) can run an ITS-S application to improve the safety and efficiency of the intersection. Depending on the applied strategy, the intersection control system will dynamically adapt the information transmitted to the vehicles in terms of SPATEMs and MAPEMs and possibly generate advice that vehicles can automatically apply at their ITS-S applications to transit the intersection while meeting the intersection control system's goals.

Figure 33 shows a situation illustrating the optimized traffic light information from V2I use case.

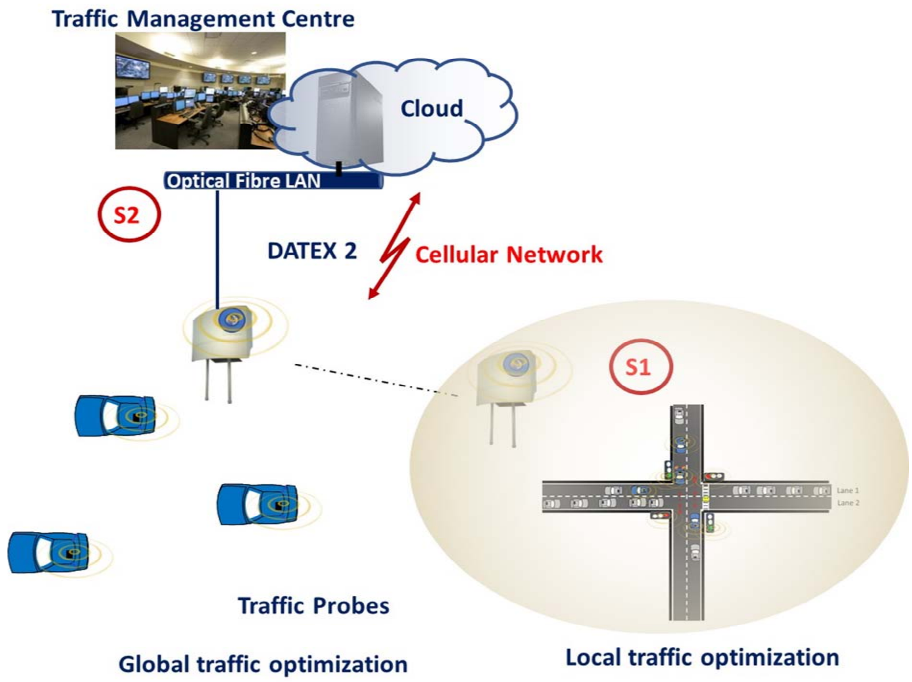


Figure 33: Collect of probe data for traffic optimization use case

5.6.5.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V Cooperation.
- C2V Cooperation.

Possible ITS-S Services:

- Any ITS-S service enabling to collect information (probe vehicles' data), and accordingly advices.

5.6.5.3 Possible implementation scenarios

S1: I2V Local Traffic Optimization:

The first ITS-S scenario refers to an I2V local traffic optimization. Vehicles affected by a hazard (e.g. broken down situation) on a specific inbound or outbound lane run an ITS-S application detecting the problem and broadcasting a DENM containing an identifier of the lane where the hazard occurs. This detailed information is used by the ITS-S application of the intersection control system to dynamically update the allowed topological in/out connections and the associated sign and time information. The updated information is then reflected in the MAPEM and SPATEM information transmitted by the associated Roadside ITS-S.

S2: I2V-C2V Global Traffic Optimization:

The second ITS-S scenario refers to an extension of the scenario 1 to any type of global road topography (not only intersections) covering a complete traffic area. In such case, cooperative vehicles and cooperative RSUs act as traffic probes and transmit pre-processed data using DATEX II protocols to a traffic management centre which can then return, using also DATEX II advice to vehicles to optimize globally the traffic.

5.6.5.4 Implementation scenario flow diagram

The following flow diagram (figure 34) illustrates described ITS implementation scenarios.

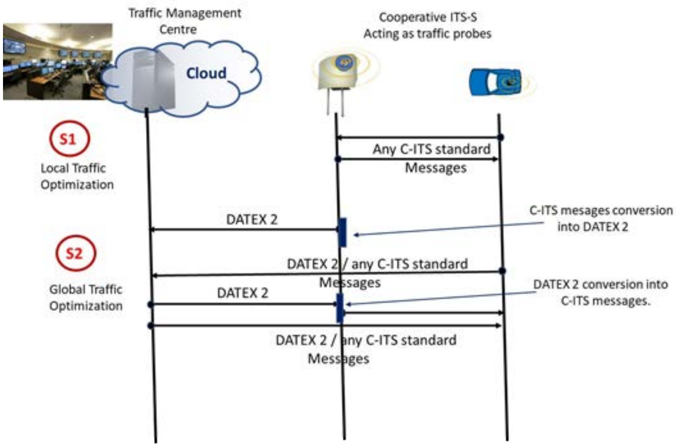


Figure 34: Flow diagram, Model 11, combining any C-ITS standard messages broadcasting into DATEX unicast

5.6.5.5 Possible implementation scenarios options

Scenario 1: The local RSU manages locally the traffic according to its augmented perception (autonomous + standard received C-ITS messages).

Scenario 2: The global traffic relative to a delimited area (e.g. region) is managed by a traffic management centre via an optical fibre LAN or a cellular network. The local RSUs may support the central system collecting data (traffic probe function) and converting them in DATEX II before providing them to the centre. The local RSU may also convert DATEX II advice received from the centre into standard C-ITS messages (e.g. CAMs, DENMs, etc.).

5.6.6 Automated GLOSA (A-GLOSA) use case

5.6.6.1 High level description

The probe I2V information can be included in CAM extensions of different types and be broadcasted by vehicles of different automation levels depending on their capability to generate that information (e.g. in/out route at intersections might be available thanks to navigation systems also at vehicles with lower automation, while information about possible participation in a vehicle string might be only available at vehicles with higher automation). As for the previous one, this implementation option implies dynamic modifications of consolidated intersection control programs by inclusion of external information received by vehicles via V2X. Therefore, it is necessary that future CAM extensions are complemented by safety containers expressing the quality and accuracy of the transmitted information (for functional safety reasons). Regarding the messages generated by the infrastructure, SPATEM and MAPEM messages would also require extensions for safety containers expressing the quality and accuracy of the provided topological, timing and speed advice information (this is again for functional safety reasons at the automated systems of receiving vehicles).

5.6.6.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- Any ITS-S service enabling to collect information (probe vehicles' data), and accordingly advices.
- MCS for collective actions.

5.6.6.3 Possible implementation scenarios

S1: I2V/V2V Local Traffic Optimization:

The augmented perception of the RSU can be used to optimize locally the traffic using MCS.

5.6.6.4 Possible implementation scenarios options

Standard CAMs a swell as SPATM and MAPEM require the addition of a safety container expressing the quality and accuracy of provided topological, timing and speed information.

5.6.7 Automated GLOSA with negotiation use case

5.6.7.1 High level description

This ITS application extends the approaches of the previously described A-GLOSA and Optimized Traffic light information with V2I. It is targeted to cooperative vehicles with high level of automation being capable to negotiate about the received speed or lane change advice with the intersection control system. Cooperative automated vehicles inform the controller in real time if the received advice is being followed or not. This additional feedback can be used by the ITS-S application at the intersection controller to further refine the traffic light phase and time algorithms and produce refined or alternative advice, such as to further optimize the traffic flow at the intersection or at intersection corridors.

5.6.7.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.
- I2V Cooperation.

Possible ITS-S Services:

- Any ITS-S service enabling to collect information (probe vehicles' data), and accordingly advices.
- SPAT/MAP services.
- MCS.

5.6.7.3 Possible implementation scenarios

S1: I2V/V2V Local Traffic Optimization:

The augmented perception of the RSU can be used to optimize locally the traffic using SPATS/MAPS or MCS. Feedback from relevant vehicles enable a real time evolution of the local traffic optimization strategy.

5.6.7.4 Possible implementation scenarios options

SPATS/MAPS can be used for release 1 cooperative vehicles, while MCS can be used for release 2 cooperative vehicles.

5.6.8 Railway level crossing use case

5.6.8.1 High level description

The potential traffic conflicting area is a zone defined between two crossing lights as depicted in figure 35.

In Europe a railway level crossing can be equipped with different devices:

- Lights, ring, two half barriers (as represented in figure 35).
- Lights, ring, two full barriers.
- Lights, ring, four half barriers.
- Lights, ring.

A railway level crossing area is a critical area since a train can be signalled at any unpredictable time. This led the main stakeholders to provide constantly information about the current state of the railway level crossing, considering that a state change corresponds to the signalisation of an event.

Then, the following states are possible:

- Nominal: The RLC is open, road users are authorized to cross.
- Abnormal situation: The RLC is presenting a defect and road users are not authorized to cross.
- Closed, signalling the arrival of a train: The RLC is closed, and road users are not authorized to cross.
- Closed, signalling railway work: The RLC is closed, and road users are not authorized to cross.

Unguarded level crossing: No information about the RLC state. Road users need to be vigilant before crossing.

Figure 35 shows a situation illustrating the railway level crossing use case.

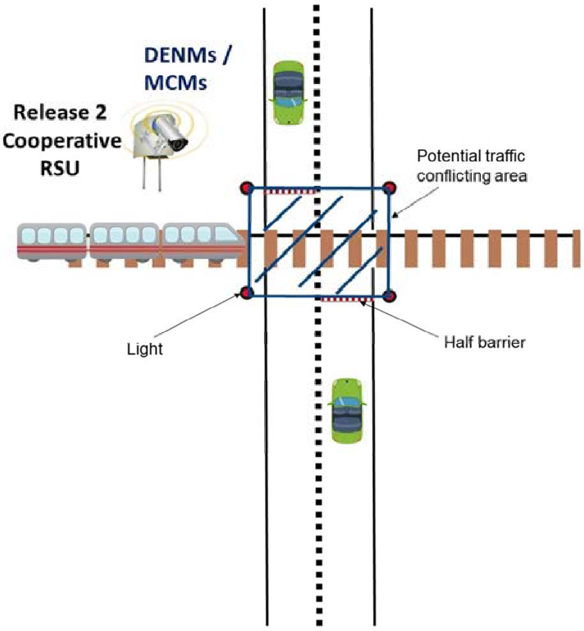


Figure 35: Railway Level Crossing (RLC) use case

5.6.8.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the most appropriate one for this use case:

- I2V Cooperation.

Possible ITS-S Services:

- DEN S.
- Optionally associated with MCS.

5.6.8.3 Possible implementation scenarios

S1: I2V DENMs broadcasting optionally associated with MCS:

DENMs signalling the RLC state are continuously broadcasted with a predefined frequency comprised between 1 and 10 Hz.

Receiving vehicle adapt their movements accordingly.

MCS can be used in case of the velocity of an approaching vehicle is excessive and presents a risk of collision at the railway level crossing level. In such case, an emergency brake can be requested.

5.6.8.4 Implementation scenario flow diagram

The following flow diagram (figure 36) illustrates described ITS implementation scenario.

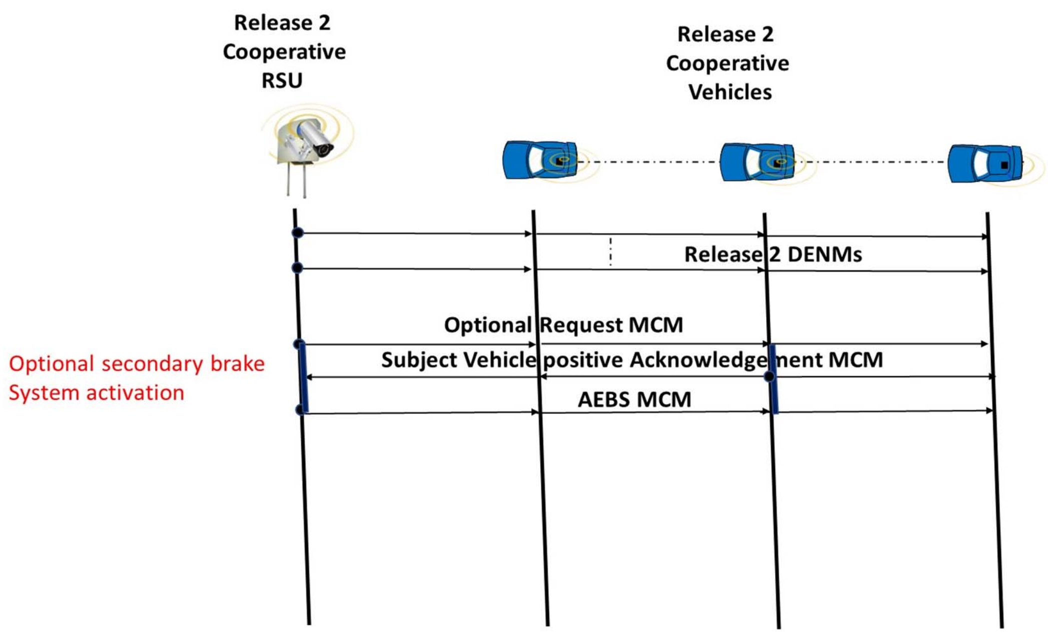


Figure 36: Flow diagram Model 12, combination of release 2 DENMs broadcasting and MCMs broadcasting

5.6.8.5 Possible implementation scenarios options

If the RSU measures a Time To Collision (TTC) of a vehicle with the RLC closed barrier less than a predefined value, this one may optionally broadcast MCMs triggering the secondary braking system (AEBS) of the vehicle to avoid collision with an approaching train.

DENMs provide the state of the RLC and then indicate all changes of state.

5.6.9 Other intersection/area crossing use case

5.6.9.1 High level description

Other types of intersections, crossing areas (e.g. bridges, vertical lift bridges, tunnels, etc.) may be protected as described here above at the level of the Railway Level Crossing.

Others notified constraints such as the vehicle size, the total weight of the vehicle, the maximum number of vehicles simultaneously authorized to cross may also condition the evolution of approaching vehicles.

If one notified constraint is not respected, the responsible vehicle can be immobilized (using MCM request) until either the vehicle conforms to the constraint, or the constraint is released.

5.6.9.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the most appropriate one for this use case:

- I2V Cooperation.

Possible ITS-S Services:

- DEN S.
- Optionally associated with MCS.

5.6.9.3 Possible implementation scenarios

S1: I2V DENMs broadcasting optionally associated with MCS:

DENMs signalling the intersection/area crossing state are continuously broadcasted with a predefined frequency comprised between 1 and 10 Hz.

Receiving vehicle adapt their movements accordingly.

5.6.9.4 Implementation scenario flow diagram

The flow diagram Model 12, in figure 36 is applicable to this use case.

5.6.9.5 Possible implementation scenarios options

If the RSU measures a Time To Collision (TTC) of a vehicle with the protected crossing area being in a state requiring the vehicle to stop, less than a predefined value, the RSU may trigger an emergency brake via MCMs.

DENMs provide the state of the protected area and then indicates all changes of state.

5.7 Advanced warning and information, VRU protection

5.7.1 ITS service introduction

VRUs protection is a key road safety domain which was the object of a set of standards identifying reference use cases, ITS functional architecture and specifying a new VRU awareness basic service intended to avoid collision between VRUs and vehicles.

However, the development and deployment time which are necessary to lead to a full benefit of such ITS application and the constant increase of some categories of VRUs critical accidents (e.g. cyclists, standing scooter drivers, motorcyclists) require to develop some short terms solutions enabling a significant improvement of the VRUs road safety before reaching a large deployment of here above identified solutions.

The CMC (Connected Motorcycle Consortium), member of the C2C-CC identified critical motorcyclists situations requiring an urgent focus to quickly improve their road safety.

5.7.2 Advanced Slow Vehicle Warning (ASVW) use case

5.7.2.1 High level description

Extends the Day1 SVW with information about slow vehicles detected by other vehicles or infrastructure units (CPMs). This is particularly beneficial when the slow vehicle itself is not C-ITS equipped and cannot warn other road users about its presence.

5.7.2.2 Possible ITS architecture and ITS-S services

Architecture A: In addition to the CAMs sent out by slow vehicles, or when the slow-moving vehicle is not C-ITS equipped at all, other vehicles and infrastructure provide object information through CPM which can be used to issue a slow vehicle warning if appropriate.

5.7.2.3 Possible implementation scenarios options

Implementation A: This implementation option refers to Architecture A. In addition to the dynamic's information in CAMs and DENMs, vehicles can make use of object information received from other vehicles or infrastructure to activate the slow vehicle warning functionality. Thus, also warnings about non-cooperative slow vehicles can be issued and thus safety is fostered even more.

5.7.3 Filtering motorcycle use case

5.7.3.1 High level description

A motorcycle and a vehicle exchange message to lower the collision risk when the presence of the motorcycle is not expected by the driver.

A motorcycle is passing a column of stationary traffic. The stationary traffic has deliberately left a gap in the queue to permit a vehicle to exit from a property on the right. The vehicle leaving the property enters the gap and assumes that they only need to look for vehicles approaching from their right, when in fact the motorcycle is approaching from the left. Issuing an alert to both vehicles to inform the driver to look to the left, and the motorcyclist to be aware of a car exiting.

Figure 37 shows a situation illustrating the filtering motorcycle use case.

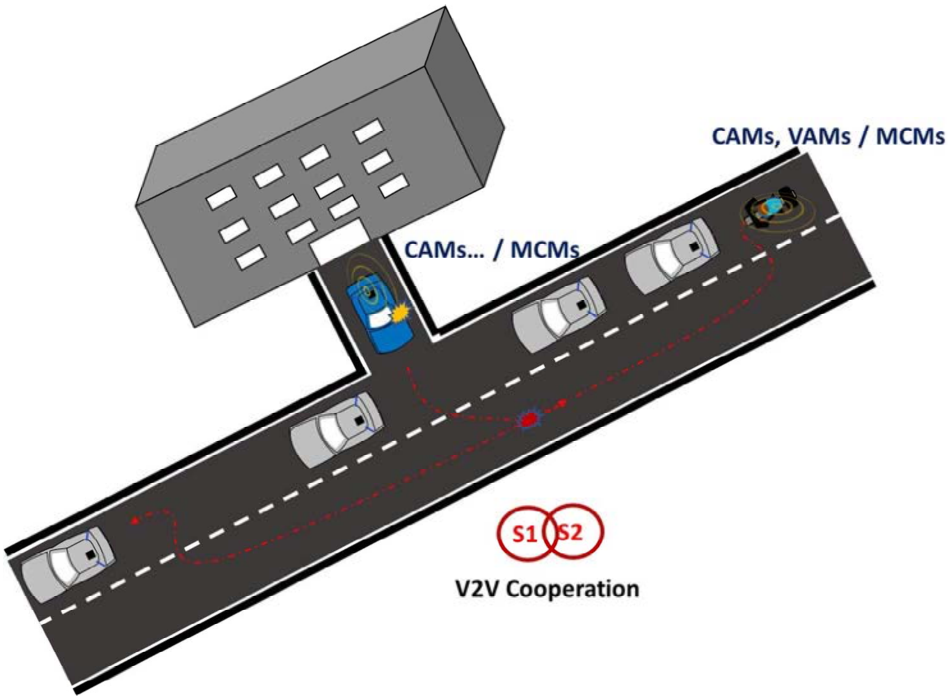


Figure 37: Filtering motorcycle use case

5.7.3.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the appropriate ones for this use case:

- V2V Release 1 cooperation.
- V2V Release 2 cooperation.

Possible ITS-S Services:

- CA basic service.
- CAS/VBS.
- MCS.

5.7.3.3 Possible implementation scenarios

S1: V2V Release 1 cooperation:

The subject vehicle which is leaving the building broadcasts CAMs. The motorcyclist is also broadcasting CAMs. Then both the subject vehicle and the VRU perceive their respective trajectories and may adapt their own accordingly to avoid a collision.

S2: V2V Release 2 cooperation:

After exchanging CAMs and VAMs, the release 2 cooperative vehicle may offer to the VRU to stop and wait for it overtaking the file of stationary vehicles. This can be achieved using MCMs. If this offer is accepted by the motorcyclist, this one can continue its trajectory without any risk of collision with the waiting subject vehicle.

5.7.3.4 Possible implementation scenarios options

The S2 is only possible if a VRU gets the capability to contribute to a manoeuvre coordination session.

5.7.4 Overtaking motorcycle use case

5.7.4.1 High level description

A motorcycle and a vehicle exchange message to lower the collision risk when the presence of the motorcycle is not expected by the driver.

A motorcycle is behind a large and/or slow vehicle in a country road setting. The rider is keen to overtake but has limited visibility of the road ahead and there are frequently cars passing in the oncoming lane. The aim is to reduce the collision risk.

Figure 38 shows a situation illustrating the filtering motorcycle use case.

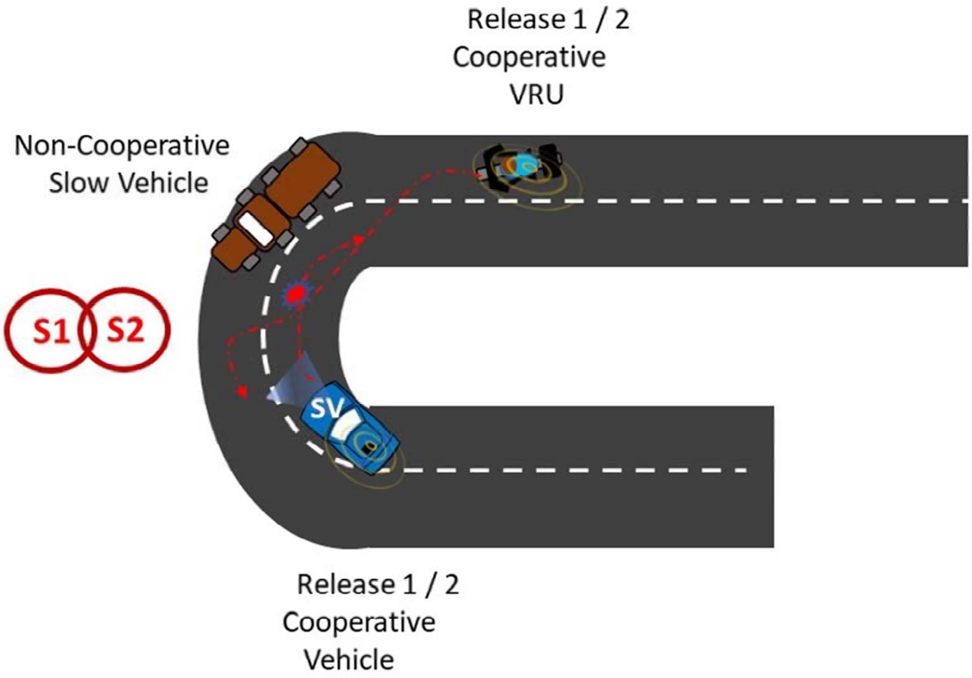


Figure 38: Overtaking motorcycle use case

5.7.4.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the more appropriate ones for this use case:

- V2V Release 1 cooperation.
- V2V Release 2 cooperation.

Possible ITS-S Services:

- CAS/VBS.
- MCS.

5.7.4.3 Possible implementation scenarios

S1: V2V Release 1 cooperation:

The Subject Vehicle (SV) broadcasts CAMs to signal its approach. It is the same at the level of the motorcyclist. Then both road users may act to avoid a collision.

S2: V2V Release 2 cooperation:

As in S1, the two cooperative road users exchange standard messages (CAMs and VAMs) to signal their approach. But the collision avoidance is achieved via a cooperative manoeuvre coordination session based on MCMs. Such approach secures the collision avoidance via the achievement of complementary actions.

5.7.4.4 Possible implementation scenarios options

The S2 is only possible if a motorcyclist gets the capability to contribute to a manoeuvre coordination session.

5.7.5 Overtaking motorcycle and turning vehicle use case

5.7.5.1 High level description

A motorcycle and a vehicle exchange message to reduce the risk of collision when the presence of the motorcycle is not expected by the driver.

A motorcycle is on a rural road behind a vehicle with a wide body (farm equipment or larger trailers) so that the turn signals are occulted or are already blind that they can hardly be seen when wanting to overtake. The tractor driver wants to turn left onto a road or field, but the motorcycle is not visible in the mirror. The aim is to reduce the risk of collision between the possibly overtaking motorcycle and the turning vehicle.

Figure 39 shows a situation illustrating the overtaking motorcycle and turning vehicle use case.

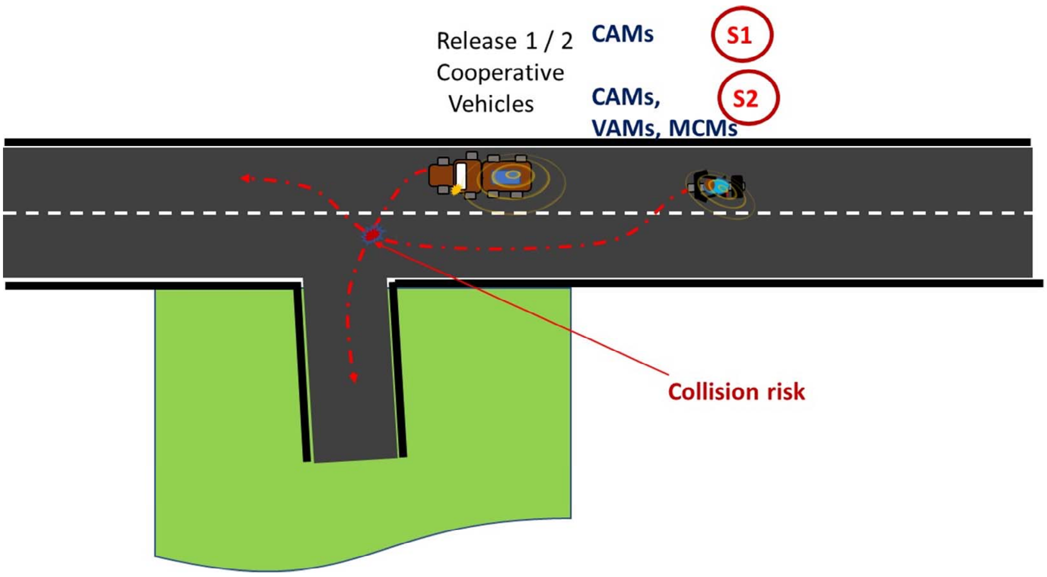


Figure 39: Overtaking motorcycle and turning vehicle use case

5.7.5.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the more appropriate ones for this use case:

- V2V Release 1 cooperation.
- V2V Release 2 cooperation.

Possible ITS-S Services:

- CAS.
- CAS/VBS.
- MCS.

5.7.5.3 Possible implementation scenarios

S1: V2V Release 1 cooperation:

The Subject Vehicle (SV) and the motorcyclist broadcast CAMs to signal their evolutions. Then both road users may act to avoid a collision.

S2: V2V Release 2 cooperation:

As in S1, the two cooperative road users exchange standard messages (CAMs and VAMs) to signal their evolutions. But the collision avoidance is achieved via a cooperative manoeuvre coordination session based on MCMs. Such approach secures the collision avoidance via the achievement of complementary actions.

5.7.5.4 Possible implementation scenarios options

The S2 is only possible if a VRU gets the capability to contribute to a manoeuvres' coordination session.

5.7.6 Turning vehicle with PTW in the blind spot use case.

5.7.6.1 High level description

A motorcycle and a vehicle exchange message to reduce the risk of collision when the presence of the motorcycle is not expected by the driver.

Figure 40 shows a situation illustrating the turning vehicle with PTW in the blind spot use case.

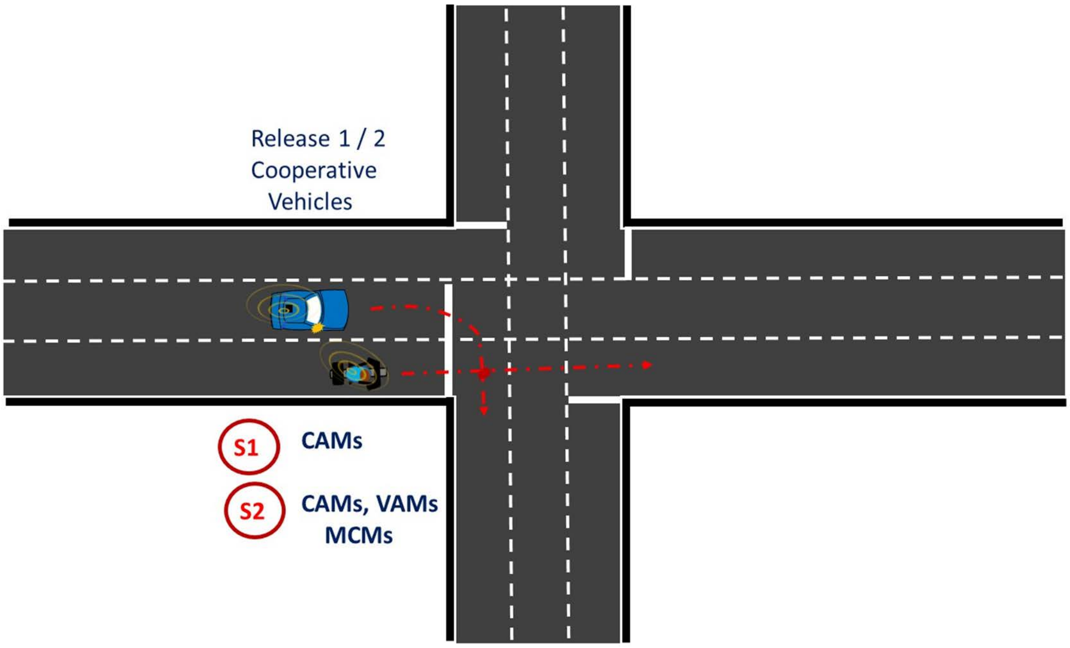


Figure 40: Turning vehicle with PTW in the blind spot use case

5.7.6.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Release 1 cooperation.
- V2V Release 2 cooperation.

Possible ITS-S Services:

- CAS.
- CAS/VBS.
- MCS.

5.7.6.3 Possible implementation scenarios

S1: V2V Release 1 cooperation:

The Subject Vehicle (SV) and the motorcyclist broadcast CAMs to signal their evolutions. Then both road users may act to avoid a collision.

S2: V2V Release 2 cooperation:

As in S1, the two cooperative road users exchange standard messages (CAMs and VAMs) to signal their evolutions. But the collision avoidance is achieved via a cooperative manoeuvre coordination session based on MCMs (the subject vehicle leaves the motorcyclist to cross the intersection before turning right). Such approach secures the collision avoidance via the achievement of complementary actions.

5.7.6.4 Possible implementation scenarios options

The S2 is only possible if a VRU gets the capability to contribute to a manoeuvres' coordination session.

5.7.7 VRU presence awareness use case

5.7.7.1 High level description

VRUs (such as bicycles and pedestrians) and other traffic participants (such as cars and trucks) are informed about their mutual presence, especially in situation where their awareness is incomplete, e.g. due to reduced visibility towards each other.

5.7.7.2 Possible ITS architecture and ITS-S services

The following ITS architectures seem to be the most appropriate ones for this use case:

- V2V cooperation.
- I2V cooperation.
- C2V cooperation.

Possible ITS-S Services:

- CAS.
- VBS.
- CPS.
- MCS.

5.7.7.3 Possible implementation scenarios

S1: V2V Cooperation:

The VRU presence awareness can be enabled by traffic participants exchanging information related to the VRU's driving environment (e.g. connected vehicles reporting about themselves or about other stations via CAMs or CPMs) and/or related to the VRU's current and estimated future kinematic state (e.g. reporting by the VRU itself or external status assessment by other connected traffic participants via CAMs and/or CPMs).

S2: I2V Cooperation:

If available, VRU presence awareness can also be offered by means of infrastructure (e.g. DENMs, CPMs). The latter may detect the VRU and traffic participants in its vicinity with its sensors and warn them about the presences of each other.

S3: C2V Cooperation:

A third option to offer VRU presence awareness is by making use of the mobile communication network. Sensor data and data obtained by V2X communication from traffic participants related to the VRU and road users in its vicinity may be gathered and disseminated over U.U links to the involved stations.

5.7.7.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

This implementation option refers to V2V cooperation. In this implementation VRUs may make connected stations aware of their presence by sharing VAMs containing their current state and predicted trajectories. Connected vehicles may in turn inform the VRUs about their kinematic states by transmitting CAMs or extended CAMs. Additionally, other connected traffic participants may make use of CPMs to share their perception related to the VRUs and other road users in its vicinity sensed through their on-board sensors.

ITS-S Scenario 2 option:

This implementation option refers to I2V cooperation. In this implementation a RSUs may detect VRUs and traffic participants that are in or could come into interaction with the VRUs. The RSU then sends out CPMs to inform the VRUs about the other traffic participants and vice-versa. Additionally, to the description of the kinematic states of VRUs and traffic participants the CPMs may include information about detected free spaces, further enhancing the awareness of connected stations.

ITS-S Scenario 3 option:

This implementation option refers to C2V cooperation. In this implementation the server gathering data with connected concerning VRUs and traffic participants in their surroundings may aggregate this data (e.g. dealing from sensors looking at the scene from different perspectives) and re-disseminate it over dedicated Unicast links. This enables to send the relevant data only to the pertinent stations. The data may be encoded in CPMs disseminated on an IP-based protocol stack or use other formats. While this implementation may mitigate flooding of the V2X communication channel for VRUs presence awareness, it is less suitable for VRU collision warning (clause 5.7.11) and VRU brake or steering intervention (clause 5.7.12) due to their much more stringent latency requirements.

5.7.8 VRU collision warning use case

5.7.8.1 High level description

VRUs and other human-driven traffic participants (i.e. of low automation level) are warned about possible collisions based on their current driving state.

5.7.8.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the more appropriate ones for this use case:

- V2V cooperation.
- I2V cooperation.

Possible ITS-S Services:

- CAS.
- VBS.
- CPS.
- MCS.

5.7.8.3 Possible implementation scenarios

S1: V2V Cooperation:

The VRU collision warning can be enabled by VRUs and traffic participants exchanging information related to their current or estimated future kinematic states. This may occur in the form of explicit collision warnings or by means of implicit information exchange based on the dissemination of the traffic participants' kinematic states.

S2: I2V Cooperation:

VRU collision warning may also be enabled by RSUs tracking traffic participants in their environment and sending them implicit or explicit collision warnings.

5.7.8.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

This implementation option refers to ITS-S scenario 1. In addition to the kinematic information in CAMs and VAMs, road users can make use of object information received from other traffic participants by means of CPMs or cases by DENMs to activate the VRU collision warning. Thus, warnings about collision risks with both cooperative as well as non-cooperative VRUs can be issued substantially contributing to traffic safety.

ITS-S Scenario 2 option:

This implementation option refers to ITS-S scenario 2. In scenarios especially safety critical for VRUs, the installation of RSUs may substantially contribute to the VRU's safety. High accuracy tracking of traffic participants is enabled by well-placed sensors covering the critical area. This allows for enhanced VRU collision warning by means of CPMs and DENMs, without requiring the presence of additional connected stations reporting the situation.

5.7.9 VRU brake or steering intervention use case

5.7.9.1 High level description

In contrast to the VRU collision warning described in clause 5.7.11, for human driven or moderately automated traffic participants, higher automation levels allow for VRU brake or steering intervention. It is based on the information exchange between connected ITS-S related to VRUs and their driving environment.

5.7.9.2 Possible ITS architecture and ITS-S services

The following ITS architectures seem to be the more appropriate ones for this use case:

- V2V cooperation.
- I2V cooperation.

Possible ITS-S Services:

- CAS.
- VBS.
- CPS.
- MCS.

5.7.9.3 Possible implementation scenarios

S1: V2V Cooperation:

The VRU braking or steering intervention can be enabled by highly automated traffic participants receiving information from other connected traffic participants related to an imminent collision risk with a VRU. As for collision warning this may occur in the form of explicit collision warnings or by implicit information exchange based on the dissemination of the traffic participants' kinematic states.

S2: I2V Cooperation:

VRU braking or steering intervention may also be enabled by RSUs tracking traffic participants in their environment and sending them implicit or explicit information for automated or highly automated driving intervention for VRU protection.

5.7.9.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

This implementation option refers to ITS-S scenario S1. In addition to the kinematic information in CAMs and VAMs, road users can make use of object information received from other traffic participants by means of CPMs or, cases, by DENMs to activate the VRU brake or steering intervention. An important difference to a simple collision warning is the higher relevance of functional safety considerations as supported by Day 3+ V2X services.

ITS-S Scenario 2 option:

This implementation option refers to ITS-S scenario S2. The equipment of RSUs with object tracking sensors in high-risk regions for VRUs allows to share this data by means of CPMs. This data can further be enhanced by including predicted trajectories of VRUs into CPMs or MCMs building a solid basis for VRU brake or steering interventions.

5.7.10 VRU safety beacon use case

5.7.10.1 High level description

ETSI TS 103 300-3 [i.15] introduces the concept of "low risk area" which conditions the dissemination of VAMs. When entering a low-risk area, the VRU attached devices stop disseminating their VAMs. The current issue is how an active VRU attached device knows that the VRU is moving in a low-risk area?

A low-risk area can be delimited by physical elements or can be delimited by a safety beacon providing delimitation information (e.g. a dedicated lane following the curvature of the road).

Moreover, it will take a long time for the equipment of all VRUs with an attached VRU device. So, many VRUs will not be protected during this long deployment time. A solution is then to use a low cost, low size, low power consumption roadside unit, which is delimiting VRU protected areas, acting as a cluster leader (even if static) and disseminating VAMs to approaching vehicles informing or alerting them of the presence of VRUs (equipped or not) in the low-risk area.

Figure 41 shows a situation illustrating the safety beacon use case.

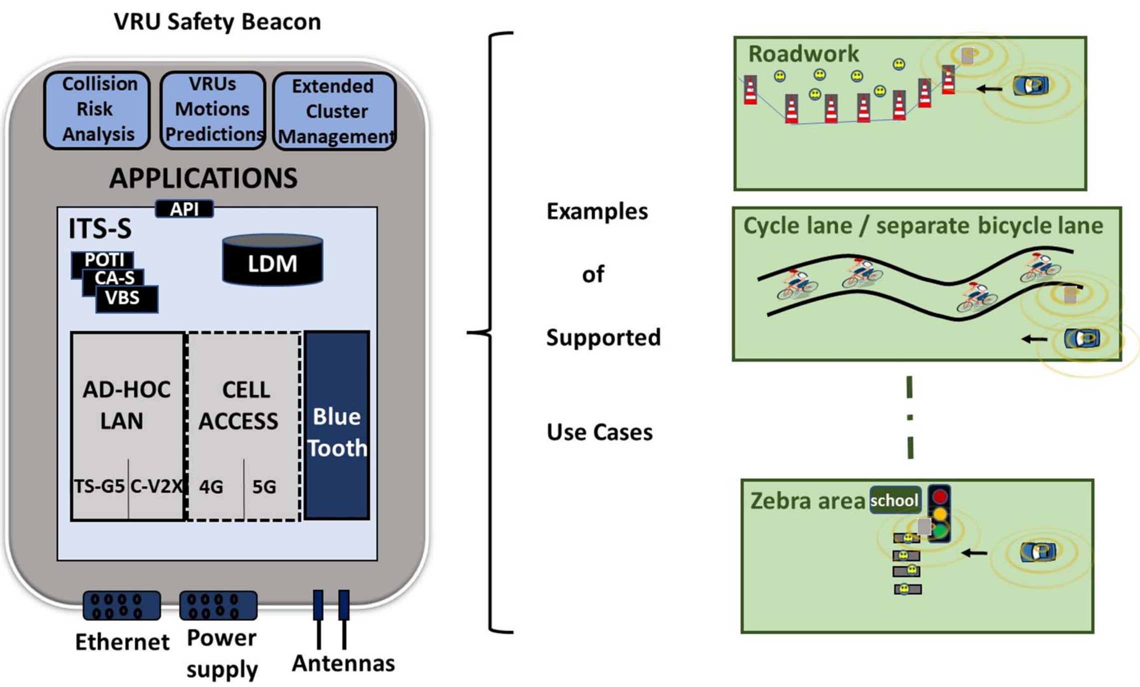


Figure 41: VRU Safety Beacon supporting use case

5.7.10.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the more appropriate one for this use case:

- I2V Cooperation.

Possible ITS-S Services:

- VBS.
- Optionally MCS in case of collision risk.

5.7.10.3 Possible implementation scenarios

S1: I2V VAMs broadcasting optionally associated with MCS:

VAMs signalling the presence of a cluster of VRUs (equipped or not) and alerting vehicles via the broadcasting of MCMs providing reference trajectory instructions (e.g. emergency brake or/and active lane keeping.

Release 2 cooperative vehicles act according to received VAMs and MCMs.

5.7.10.4 Implementation scenario flow diagram

The following flow diagram (figure 42) illustrates the described ITS implementation scenario.

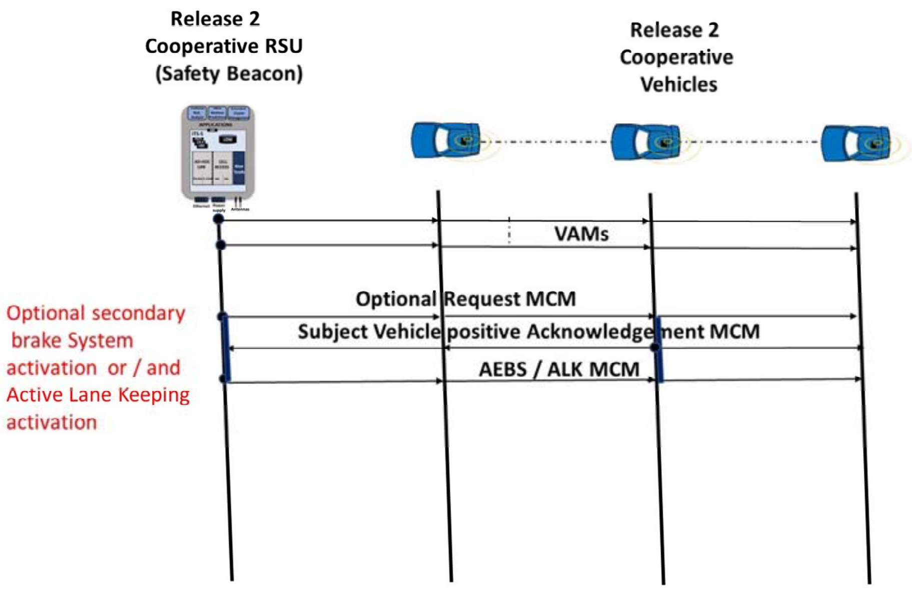


Figure 42: Flow diagram Model 13, combination of VAMs broadcasting with MCMs broadcasting

5.7.10.5 Possible implementation scenarios options

The safety beacon has the capability to detect the presence of VRUs (equipped or not) in the low-risk area and then, acting as a cluster leader signals them using VAMs.

In case of a collision risk detected by measuring a TTC less than a predefined value (e.g. 2 seconds), MCM request can be broadcasted to instruct release 2 cooperative vehicles presenting risk of entering the low-risk area either to stop (AEBS triggering) or to remain in lane (ALK triggering if not activated).

5.7.11 VRU complex interaction use case

5.7.11.1 High level description

In case the VRUs are equipped with personal ITS Stations, or ITS Stations attached to the VRU vehicles, the VRUs can:

- Increase their visibility by sending out VAMs, enabling the car to calculate collision risk and derive appropriate actions like driver warning or preparation of the onboard active safety systems.
- Increase their perception by receiving CAMs or other messages like CPMs or DENMs, allowing to also warn the VRU, which in many situations is very meaningful, especially since the VRU is willing to take action to prevent the accident.
- In a later instance cooperative with other road users to execute coordinated manoeuvre such as it can be anticipated with vehicles manoeuvre coordination.

The first two points are especially advantageous in situations where no other ITS equipment (like ITS-equipped road infrastructure) is nearby. In addition, the VRU device can have information that is not easy to find from outside, starting with the sub-profile of the VRU type, its stability status and its future trajectory, the latter being especially true for ITS devices attached to VRU vehicles (bicycles, scooters) whose degrees of freedom are much less than those of pedestrians.

The latter can enable many manoeuvres that pose a risk for the VRU. This can for example be passing a stationed truck at a red light to access the dedicated bike waiting area in front of the lane or enable e-scooter and cyclist coordination when crossing each other at bike path.

However, such critical situation requires that cooperative vehicle(s) and VRU(s) have the capability to perceived broadcasted signals.

Figure 43 shows a situation illustrating the VRU complex interaction use case.

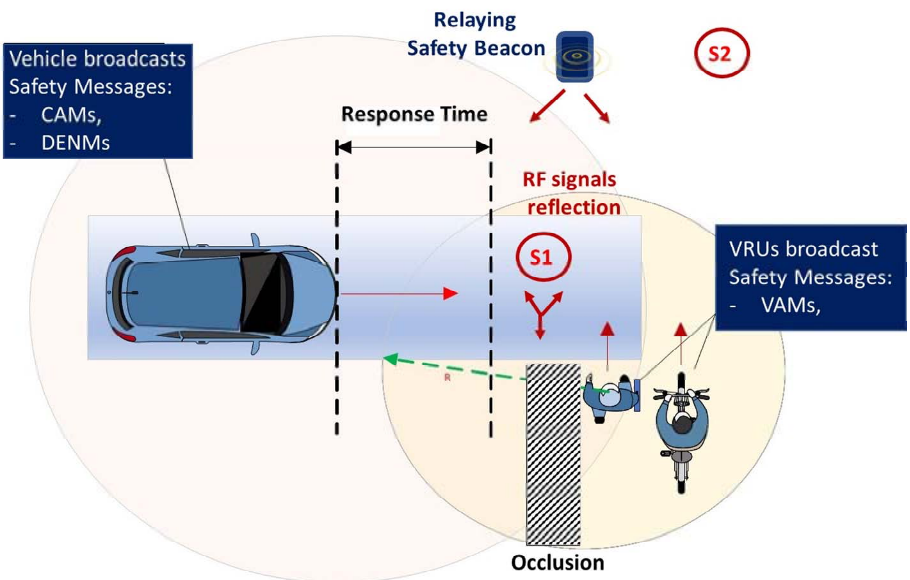


Figure 43: Complex interaction situation use case

5.7.11.2 Possible ITS architecture and ITS-S services

The following ITS architectures seem to be the more appropriate ones for this use case:

- RF signals are reflected by the road surface and infrastructure.
- I2V Cooperation.

Possible ITS-S Services:

- Any basic service available at the level of cooperative vehicles and VRUs.

5.7.11.3 Possible implementation scenarios

S1: Verification that the standard messages broadcasted by cooperative vehicles and VRUs are well reflected by the road infrastructure:

During the long period of C-ITS assessment, it has been proved that RF signals are easily reflected by the road surface and elements of the road infrastructure. For critical situations such reflectivity property needs to be checked.

S2: Addition of a safety beacon (RSU) acting as repeater of received standard messages:

If broadcasted standard messages cannot be received by cooperative vehicles or/and VRUs, a safety beacon acting as repeater can be appropriately positioned to enable such perception.

5.7.11.4 Possible implementation scenarios options

If a safety beacon (low cost RSU) is used to relay received standard messages, this will be achieved on top of layer two for services which are not benefiting of the geonetworking capability. It can be automatically achieved for DENMs which are using the geonetworking.

5.7.12 Interactive VRU crossing use case

5.7.12.1 High level description

The application was described in a documentation published by 5GAA but so far not been tested in an open environment.

A VRU (e.g. pedestrian, cyclist, etc.) expresses intent to cross a two-lane road. Vehicles approaching the area in which the VRU intends to cross receive the message and send an acknowledgement and a participation/refusal message. They subsequently adapt their behaviour to allow the VRU to cross safely. Upon receiving these positive acknowledgements from the vehicles, the VRU may cross the street.

Upon reaching the other side of the street, the VRU may send another message to the vehicles confirming that it has safely crossed.

The main process of the applications is as follows:

- A VRU approaches a street on a sidewalk.
- The VRU then expresses the intent to cross the street on a location where crossing can be risky.
- Approaching vehicles receive the message of the crossing intent and perform target classification to determine if the message is relevant for them.
- If a vehicle determines that it can accommodate the request, it acknowledges the VRU and notifies nearby vehicles that it is participating in the request.
- When the VRU receives sufficient evidence that it is safe to cross (may vary with number of lanes and vehicles present), crossing is initiated.
- While the VRU is crossing, his/her personal device sends information notifying stopped vehicles of its progress.

When vehicles are safe to proceed after the VRU crosses, they begin moving again.

5.7.12.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the more appropriate one for this use case:

- V2P.

Possible ITS-S Services:

- To be identified: Possibly an extended VBS or an extended MCS.

5.7.12.3 Possible implementation scenarios

S1: V2P cooperation supported by a new basic service which needs to be specified:

Like in MCS, a negotiation has to be initiated between one VRU and one/several cooperative subject vehicles which are moving in direction of the VRU. A manoeuvre coordination of the vehicle can be proposed and accepted to leave the pedestrian safely crossing the road.

5.7.12.4 Possible implementation scenarios options

Further considerations of this topic are:

The implementation for an interactive VRU crossing can lead to some difficulties if the pedestrians are executing illegal crossing, therefore it is important to clarify and delimit the application to areas where this is possible. An alternative protection system needs to be considered when the pedestrian is executing an illegal crossing.

5.7.13 Extended cluster management use case

5.7.13.1 High level description

As above described, in case of an active VRU safety beacon, the cluster management is simplified, and the beacon automatically becomes the cluster leader in the delimited low-risk area. VRU cluster management has been the object of the STF 565 and is fully described in the ETSI TR / TS 103 300 serie (ETSI TR 103 300-1 [i.13], ETSI TS 103 300-2 [i.14], ETSI TS 103 300-3 [i.15]).

Moreover, for VRUs which present a high-risk profile (high vulnerability level or high velocity like cyclists or scooters), it could be necessary to consider them out of the VRU cluster and keep them disseminating their VAM for enabling vehicles quickly detecting a dangerous behaviour (stability problem, unexpected change of trajectory/velocity) which may require an immediate evolution of the collision avoidance strategy. Sending out individual VAMs will be especially important close to the borders of the safe zones.

5.7.13.2 Possible ITS architecture and ITS-S services

The following ITS architecture seems to be the most appropriate one for this use case:

- V2P.

Possible ITS-S Services:

- Evolution of the VAM.

5.7.13.3 Possible implementation scenarios

S1: V2P cooperation including extended cluster management:

Even being member of a cluster, a VRU which is identified as particularly vulnerable may continue to broadcast VAMs. Its particularity can be identified in the VAM to enable receiving vehicle(s) to adapt their collision avoidance strategy.

5.7.13.4 Possible implementation scenarios options

Such extended cluster management option needs to be based on a deep analysis of VRU "vulnerability profiles" which are justifying such approach.

5.8 Dynamic navigation

5.8.1 ITS service introduction

Automated dynamic navigation is the first application to consider. Navigation requires that the automated vehicle be following the road infrastructure which is built for this purpose. They are supported by road horizontal marking and vertical signs. Road horizontal marking enables sensors (e.g. front camera) to stay in the marks (e.g. active lane keeping) and signal possibilities or not to overtake other vehicles. Vertical signs are used for providing traffic code rules and signals static road hazards. However, road horizontal marking like traffic signs have been made for human driven vehicles and are not always appropriate to automated vehicles which may require expensive artificial intelligence to be recognized. Moreover, road horizontal marking like vertical signs may be occulted during adverse weather conditions (rain, fog, snow, etc.), road degradation and hidden by other vehicles such as trucks. It is then required to find some redundant systems to overcome these economical and perception problems.

Dynamic navigation means that a given initial itinerary may become impossible due to an unexpected road hazard which may disturb the traffic in one portion of the itinerary. This means that an alternative route needs to be identified to overcome this problem so changing the initial itinerary. Moreover, even if the initial itinerary stays possible, it could become more efficient, for traffic optimization and pollution reduction to balance the overall traffic between different itineraries.

In case of road hazard, the instructions of the road authorities have to be followed, as they bear the sovereign responsibility for the population. Individual will not have to stand in the way.

5.8.2 Detour management use case

5.8.2.1 High level description

A lot of area hazards may disturb a vehicle itinerary during its evolution from an origin to a destination (e.g. area which are not authorized to the vehicle type, flooding, fire, closed road (roadwork, closed bridge/closed railway level crossing, etc.), etc.).

Figure 44 considers a low emission zone which is not authorized to vehicles not using electrical propulsion power as it may appends in many cities. In such case, the not-authorized vehicle will have to change its itinerary if planned to cross the city.

Figure 44 shows a situation illustrating the detour management use case.

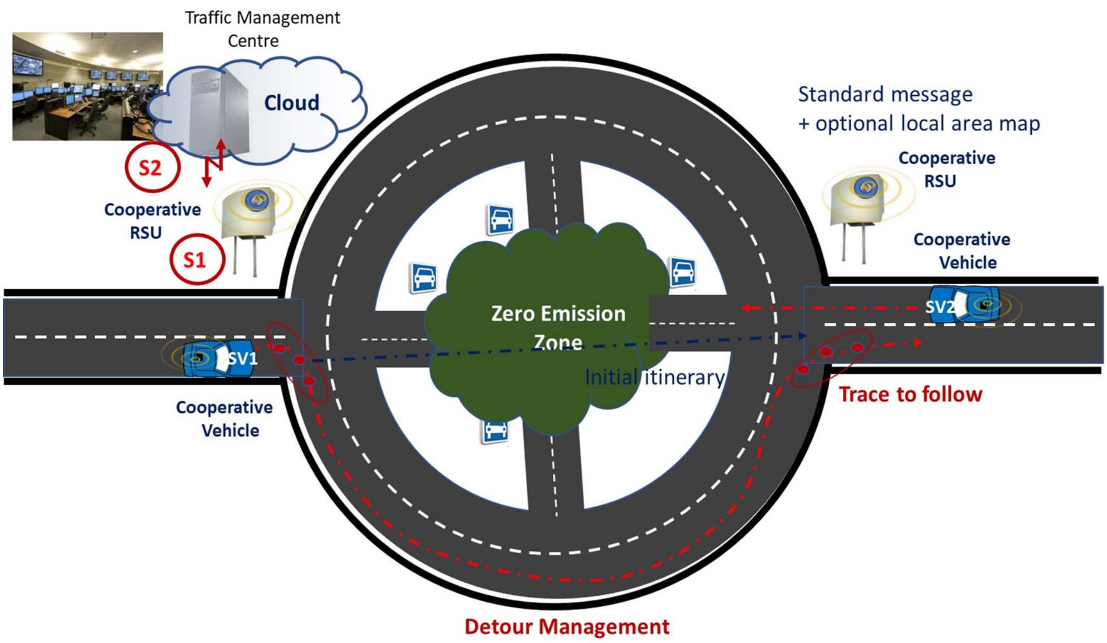


Figure 44: Detour management use case

5.8.2.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V cooperation.
- C2V cooperation.

Possible ITS-S Services:

- Extended DENMs or IVIMs providing traces (groups of way points) to follow according to its targeted destination and encountered topographic situations offering several possibilities (recommended choice).

5.8.2.3 Possible implementation scenarios

S1: I2V Cooperation:

A connected vehicle which is not authorized to enter in a planned area receives from a local RSU advice to change its itinerary. The advice provides traces to follow when several possibilities exist. If the number of traces is too important, a local map can be optionally provided indicating the recommended itinerary.

If the destination of the user is inside the not-authorized area, a Parking Availability information can be provided to the user (see the PAS in clause 5.10) to park and Ride using other available transportation services.

S2: C2V Cooperation:

A connected vehicle which is not authorized to enter a planned area may request to a traffic management centre to provide him a recommended detour itinerary enabling to reach its destination without having to cross the restricted area. Related to its destination, it may request to be supported to park its vehicle before accessing the restricted area and then use the transports facilities available inside the restricted area (Park and Ride).

5.8.2.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

Existing ITS-S basic services such as IVI or DEN could be extended to support such ITS application. If the broadcast mode is used, several messages could be necessary according to the planned destination of the subject vehicle as several detours could be possible. In some circumstances, the detour could be important, so requiring many traces to provide when several trajectories' possibilities exist.

ITS-S Scenario 2 option:

Existing ITS-S basic services such as IVI or DEN may also be extended to support such ITS-S application. But in this case, it would be preferable that the user sends a request to the traffic management centre which could propose him the right itinerary to follow according to its initial destination.

5.9 Contextual dedicated corridor management

5.9.1 ITS service introduction

The deployment of new vehicle types in terms of propulsion system or automated level, as well as new usages of vehicles (vehicle sharing and pooling, new public transport) combined to priority given to some special vehicles (e.g. emergency vehicles) lead to consider the dynamic management of traffic corridors which can be reserved according to given contextual traffic conditions to classes of vehicles which satisfy predefined conditions.

Five types of use cases are identified below although many others could be imagined in the future according to road infrastructures and vehicles evolutions.

When the context is referred to, one key context element is the "traffic context" or fluidity which can be characterized when considering the traffic density and the traffic flow rate such as represented in figure 45.

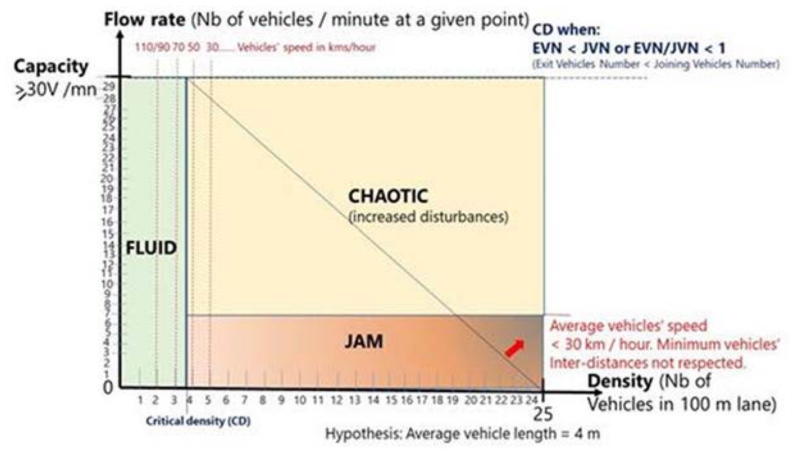


Figure 45: Proposed characterization of the traffic fluidity

This traffic fluidity characterization has been proposed by the French project PAC V2X and used during the project experimentation on motorway and urban area.

NOTE: This model does not include VRUs which could lead to a much higher density.

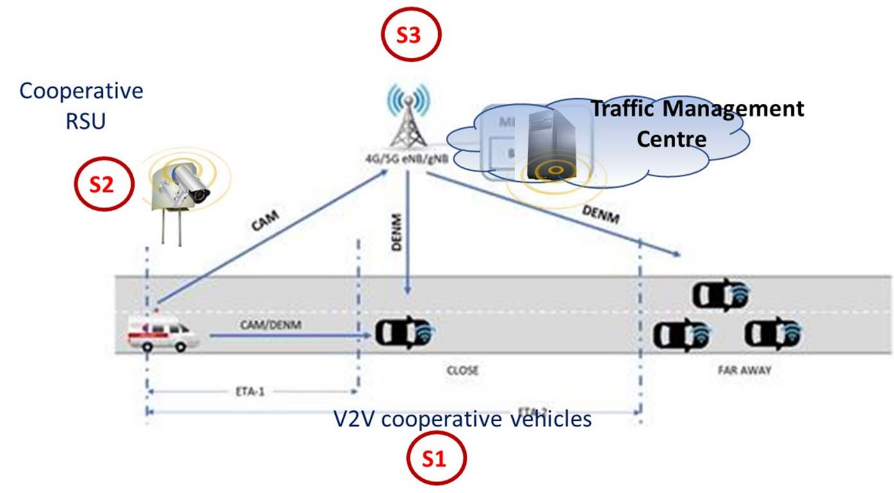
Taking the motorway example, when the traffic context is fluid on all the lanes, a dedicated corridor does not need to be created, but when the traffic becomes chaotic or when there is a traffic jam, it may become necessary to give the priority to some specific vehicles by assigning them a dedicated corridor and avoiding that this assigned corridor be used by other non-authorized vehicles.

5.9.2 Corridor dedicated to an emergency vehicle, rescue/recovery, prioritized/safety vehicle use case

5.9.2.1 High level description

In chaotic or traffic jam situations, it becomes necessary to facilitate the evolution of emergency vehicles which are active to provide a rescue to road users and more generally people in danger. This can be achieved by reserving a dedicated corridor which cannot be used by other non-authorized vehicles.

Figure 46 shows a situation illustrating the corridor dedicated to an emergency vehicle use case.



NOTE: Extension of the model provided by the European project 5G CARMEN.

Figure 46: Corridor dedicated to an emergency vehicle use case

5.9.2.2 Possible ITS architecture and ITS-S services

The following ITS architectures are appropriate for this use case:

- V2V cooperation.
- I2V cooperation.
- C2V cooperation.

Possible ITS-S Services:

- Several ITS- services can be used. CAS and DENS are the basic services which are considered here, but of course, CPS and MCS could as well be used.

5.9.2.3 Possible implementation scenarios

S1: V2V Cooperation:

The dedicated corridor is dynamically created by the emergency vehicle which signals its approach by broadcasting standard messages indicating that it is in an active rescue service.

Upon receiving such information, relevant cooperative vehicles need changing of lane as soon as possible to give way to the emergency vehicle. Once the emergency vehicle passed by, the relevant vehicles may return in their initial lane.

S2: I2V Cooperation:

Upon detection of the approach of an emergency vehicle in a rescue mission, the RSU signals it so asking all cooperative vehicles to release the lane in which the emergency vehicle is moving. Once the emergency vehicle overtook concerned cooperative vehicles, they may be back in their initial lane.

S3: C2V Cooperation:

Upon detecting the approach of an emergency vehicle in a rescue mission, the traffic management centre sends unicast request to relevant connected vehicles to give way to the emergency vehicle. Once the emergency vehicle overtook them, the traffic management centre may re-open the corridor used by the emergency vehicle to other vehicles.

5.9.2.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

The emergency vehicle is a release 1 cooperative vehicle using CAMs indicating in its emergency container that the vehicle is in an emergency operation. Consequently, all relevant cooperative vehicles need giving way to the emergency vehicle as soon as possible acting according to possibilities offered by the current traffic context.

ITS-S Scenario 2 option:

The RSU detects the approach of an emergency vehicle in operation via its received CAMs. Then, the RSU broadcasts DENMs "emergency vehicle approaching" so implicitly requesting relevant cooperative vehicles to give way to it. MCMs could also be used for release 2 cooperative vehicles.

Upon reception of DENMs or/and MCMs, the relevant cooperative vehicles need giving way to the emergency vehicle as soon as possible according to received information and possibilities offered by the current traffic context.

NOTE: The use of MCMs could be precise in actions to undertake and could enable a greater synchronization of manoeuvres to be achieved.

ITS-S Scenario 3 option:

The traffic management centre detects the approach of the emergency vehicle in each area via received CAMs. As for S2, the traffic management centre may send instructions to relevant vehicles using Unicast links to organize the priority evolution of the emergency vehicles. DENMs or MCMs can be sent to relevant vehicles.

5.9.3 Active highway corridor for electrical vehicles reloading use case

5.9.3.1 High level description

The generalization of the Electric propulsion, especially at the truck and public transport level, requires an electrical vehicle autonomy which cannot be reached using embedded batteries only. Moreover, the recycling of batteries is likely to become a problem with the increasing number of electric vehicles. Solutions are being investigated by several E.U member states to cope with this problem (for example the German/Swedish partnership ERS (Electric Road Systems)). In France, the E-way corridor project was started between the region Ile de France and Normandie to study several solutions to transfer electrical energy from the road to vehicles.

In this case, a lane may be equipped with active electrical charging systems and managed by distributed RSU or and a central traffic management centre regulating the lane access according to the observed traffic context. In case of chaotic traffic or traffic jam detection, the lane can then be only reserved for electrical vehicles equipped with a relevant charging system. But if the traffic is fluid, the electrically active lane may be shared with other types of vehicles.

Figure 47 shows a situation illustrating the active highway corridor for electrical vehicles reloading use case.

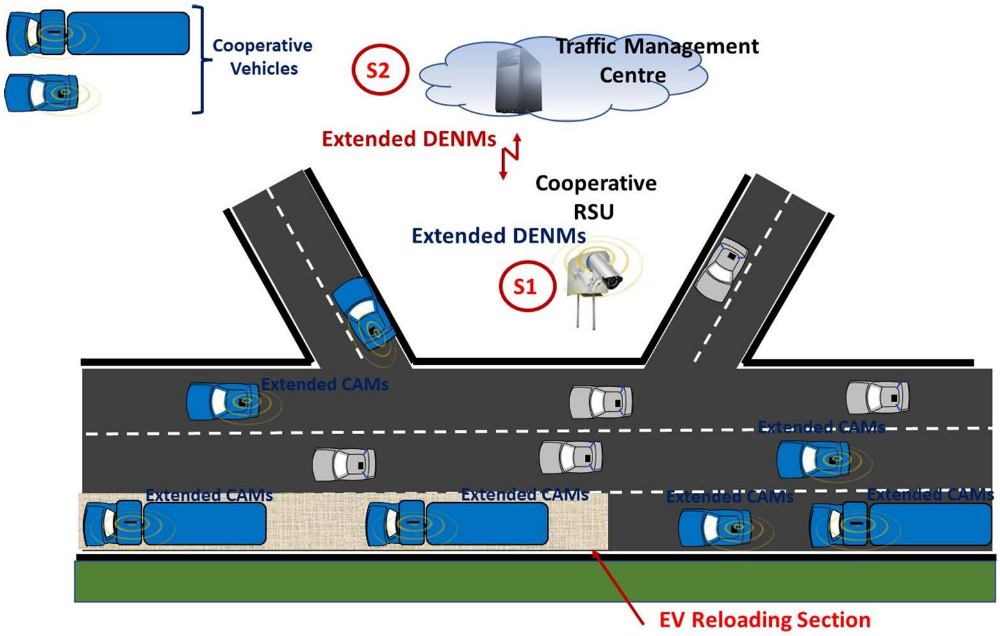


Figure 47: Active highway corridor for electrical vehicle reloading use case

5.9.3.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V cooperation,
- C2V cooperation.

Possible ITS-S Services:

- Extension of the CAM indicating the type of propulsion energy being used and its collection type and an extension of the DENM signalling EV reloading sections and associated accessing rules can be specified.

MCS can be used during traffic jam and chaotic period to request the removal of non-conforming vehicles from the EV reloading section.

5.9.3.3 Possible implementation scenarios

S1: I2V Cooperation:

- Cooperative RSU signals the presence of an EV reloading section ahead. This is including the type of reloading technology being used and access rules for non-EV vehicles.
- Receiving vehicles may use the EV reloading section if conforming to reloading technology and according to applicable traffic regulation rules.

S2: C2V Cooperation:

The traffic management centre informs conforming EV of the presence of an EV reloading section. The information includes the type of reloading technology being used and traffic regulation rules for non-EV.

The traffic management centre receives constantly extended CAMs from cooperative vehicles to identify the relevant vehicles to address (U.U link) when necessary.

5.9.3.4 Implementation scenario flow diagram

The following flow diagram (figure 48) illustrates the described ITS implementation scenarios.

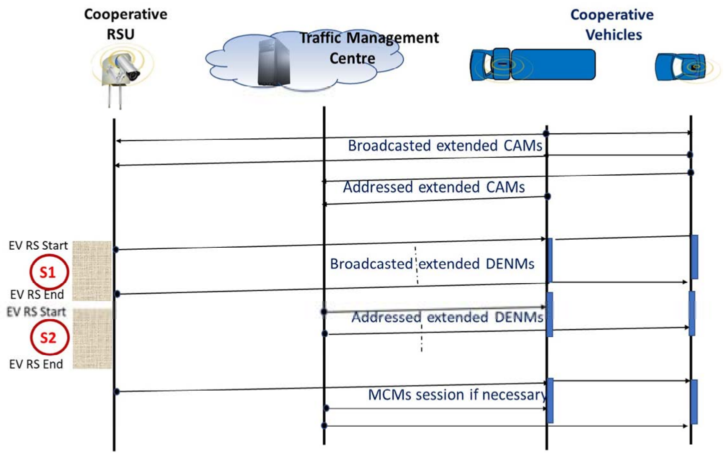


Figure 48: Flow diagram Model 14, CAMs, DENMs and MCMs broadcasting

5.9.3.5 Possible implementation scenarios options

ITS-S Scenario 1 option:

RSU broadcasts extended DENMs signalling the presence of an EV reloading section, the reloading technology to be used and traffic rules to respect for non-EV.

RSU receives and analyses extended CAMs to filter vehicles using MCMs in case of heavy traffic (chaotic or traffic jam) in the EV reloading lane.

ITS-S Scenario 2 option:

The traffic management centre receives, and analyses extended CAMs to detect relevant EVs which are conforming to the EV reloading technology being used. When approaching an EV reloading section and leaving it, the traffic management centre informs relevant vehicles of its presence.

If a non-EV is using the EV reloading lane without respecting the traffic rules, this one can be instructed to leave it via MCMs requests.

5.9.4 Corridor dedicated to other priority vehicles use case

5.9.4.1 High level description

Other types of priority vehicles having a specific permission may share one or several dedicated corridors. The usage rules may include specific traffic conditions criteria.

For example, when the traffic is fluid, all existing lanes may be used by any type of vehicles, but when the traffic becomes chaotic or in case of traffic jams, dedicated corridors can be created and reserved to authorized vehicles which have a recognized permission:

- Fully automated vehicles.
- Pooled vehicles which are used by several occupants.
- Road operators' vehicles which are used for the road infrastructure maintenance or interventions during critical winter and other bad weather situations such as flooding, snow fall, etc.

5.9.4.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V cooperation.
- C2V cooperation.

Possible ITS-S Services:

- When necessary, extension of the CAM indicating the object of the vehicle which provides it a particular priority in accessing an identified corridor. If necessary, extension of the DENMs to signal the presence of a dedicated corridor for vehicles complying to associated access rules and traffic conditions.

MCS can be used during traffic jam and chaotic period to request the removal of non-conforming vehicles from the considered corridor.

5.9.4.3 Possible implementation scenarios

S1: I2V Cooperation:

Cooperative RSU signals the presence ahead of a particular corridor dedicated to the support of a specific purpose. This is including the object of the priority and associated rules to be respected for granting an access authorization. This may also be including traffic conditions for non-conforming vehicles getting an access right.

S2: C2V Cooperation:

The traffic management centre informs conforming subject vehicles of the presence of a dedicated corridor which can be used by them. The information includes the object of the priority and the associated rules to be respected for granting an access authorization.

If necessary, the traffic management centre receives constantly extended CAMs from cooperative vehicles to identify the relevant vehicles to address (u.u link) when necessary.

5.9.5 Hard Shoulder Running use case

5.9.5.1 High level description

On routes with regular recurring high utilization during for example commuter traffic, opening the hard shoulder is an option to raise traffic flow on the existing road network. The EU EIP Handbook for ITS Core Services [i.9] describes the process for Hard Shoulder Running (TMS-04) in detail. Figure 49 shows a common installation for hard shoulder running.

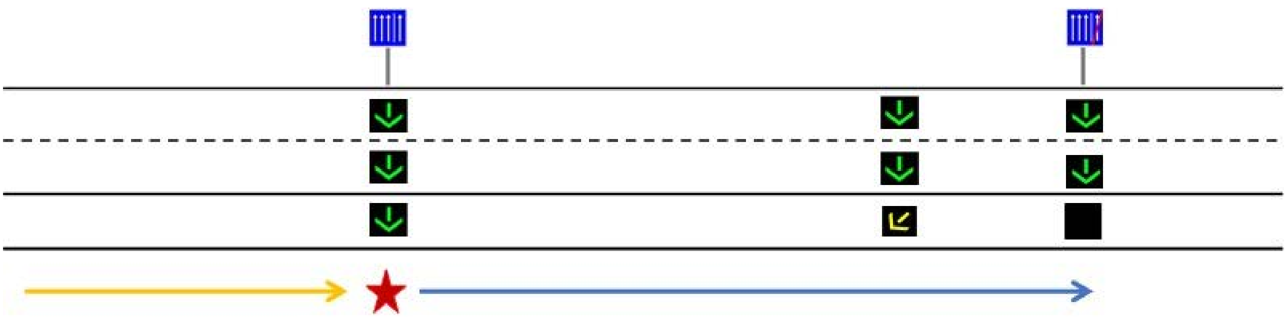


Figure 49: Hard Shoulder Running

I2V cooperation provides information to vehicles consisting of the available lanes on the road segment including optional speed restrictions. In addition, V2V messages can be used as a trigger to open the hard shoulder or sending out clearance orders quicker, for instance if a "Stationary Vehicle" DENM is received, which indicates a safety risk on the road. Once the safety risk is removed, the hard shoulder can be reopened if necessary.

5.9.5.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- V2V Cooperation.

- I2V Cooperation.

Possible ITS-S Services:

- V2V CAM, DENM.
- I2V IVI.

5.9.5.3 Possible implementation scenarios

S1: I2V Cooperation:

Infrastructure RSU send IVI regarding available lanes on a road segment and orders in case of hard shoulder clearance.

Vehicle CAM and DENM can be used as traffic jam indicator for the road operator (infrastructure) to open or close the hard shoulder. Indicators could be:

1) Average vehicle speed and number of vehicles (CAM).
2) Stationary vehicle on the road and traffic jam detected (DENM).

5.9.6 Roadwork warning (long-term) use case

5.9.6.1 High level description

I2V cooperation provides information to vehicles on current valid roadwork and associated constraints. The information refers to long term roadworks and can include signalling information such as forbidden overtaking, forbidden access to special vehicle categories, alternative routes (see detour management), as well as topological information about modified road layouts.

In particular, the information may include a systematic period of road closing from one staring hour to an ending hour.

This could be the object of a DEN Service update.

5.9.6.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V cooperation.
- C2V cooperation.

Possible ITS-S Services:

- DENS can be used to inform road users of long-term roadwork activities. This could require an extension.

5.9.6.3 Possible implementation scenarios

S1: I2V Cooperation:

- Cooperative RSU signals the presence ahead of a long-term roadwork and provides details about specific mobility constraints.
- Receiving vehicles apply the communicated constraints.

S2: C2V Cooperation:

The traffic management centre informs approaching vehicles of the presence of a long-term roadwork and its currently applicable traffic constraints.

5.9.6.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

- RSU broadcasts extended DENMs informing about a long-term roadwork ahead and its associated current traffic restrictions.
- Receiving vehicles apply the communicated traffic restrictions.
- RSU receives and analyses broadcasted CAMs to filter vehicles which are not respecting the traffic restrictions, using MCMs.

ITS-S Scenario 2 option:

The traffic management centre receives, and analyses addressed CAMs to detect relevant subject vehicles which are approaching a long-term roadwork area. When approaching a long-term roadwork area, the traffic management centre addresses DENMs to the concerned subject vehicles to inform them of the current traffic restrictions existing at the level of the roadwork.

If a subject vehicle is not respecting the communicated traffic restrictions, the traffic management centre may address it MCMs to reinforce the traffic restrictions.

5.10 POIs management

5.10.1 ITS service introduction

Several aspects of POIs management are already considered in clause 5.2 (clauses 5.2.9 and 5.2.10) and SDOs' publications.

They have been included in clause 5.2 because they are mandatory for the full operationality of vehicles and are supported by dedicated ADASs (e.g. TPMS which is mandatory at the E.C level and vehicle energy monitoring system).

Other POIs are numerous and for the time being are not part of the present document, excepted the Parking Management Service as many POIs have associated to them a parking to store vehicles when their users are not using them.

Several types of parking need to be considered and their related points of interest can be identified to be considered in further versions of the Basic Set of Applications.

Moreover, the parking management application may consider several steps in the parking process, since the identification of available parking at indicated destination(s):

- The selection of an appropriate parking and parking space and its booking.
- The guiding to the parking entry.
- The possibility of the use of an automated parking valet.
- Then the payment of the parking when leaving it.

Figure 50 illustrates the various steps of the parking management process.

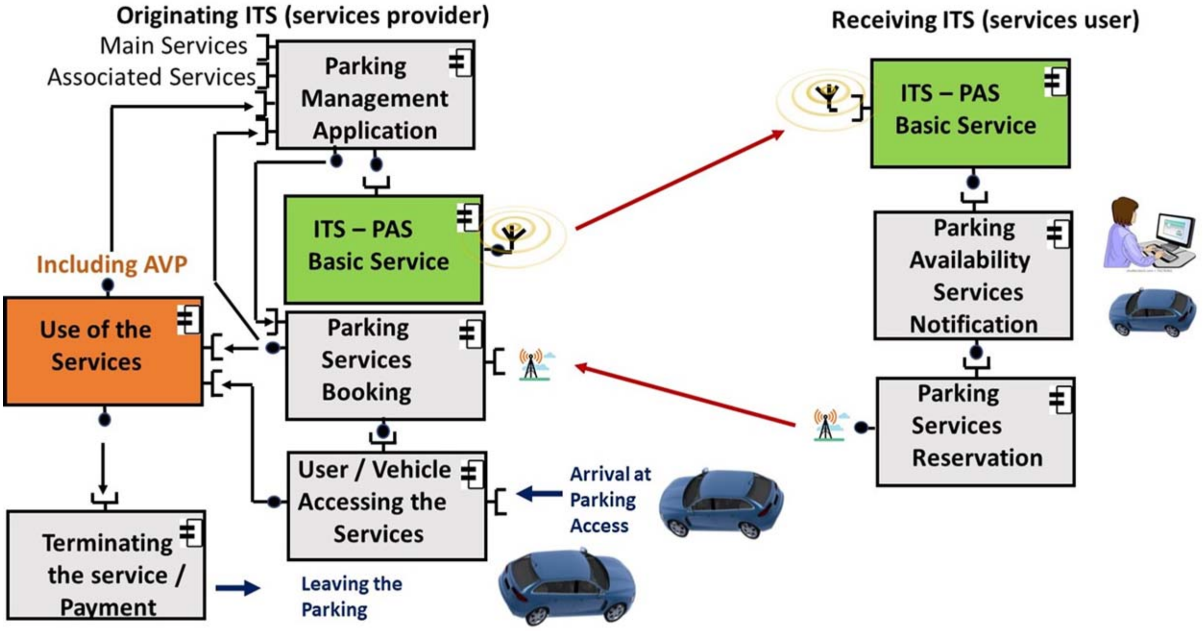


Figure 50: Illustration of the parking management ITS service process

This ITS service process can be used as a reference model for many POIs which may include these different phases (availability notification, reservation, use, payment).

A generic approach for POI Availability Service specification is introduced in clause 5.10.6.

5.10.2 Parking Availability Service use case

5.10.2.1 High level description

The Parking Availability basic Service (PAS) is a service which provides real time information about the availability of main user' parking services (vehicle parking, parking space types and services, parking space reservation and payment) and optionally Related POIs locally available (for example: Valet Parking, Energy supply, Tyre Pressure gauge and adjustment, vehicle washing, etc.).

This information is provided via a standard message POIM-PA (Parking Availability Message) which can be locally broadcasted, provided on demand (unicast pulling mode) or more systematically addressed on a contractual basis (unicast pushing mode).

5.10.2.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V Management.
- C2V Management.

Possible ITS-S Services:

- Parking Availability Service and Related POIs services.

5.10.2.3 Possible implementation scenarios

S1: I2V Management:

Cooperative RSU signals the presence ahead of different types of parking and provides real time information about the availability of provided services (parking and Related POIs services). Possibility to reserve services and payment conditions are also optionally available.

Receiving vehicles may then reserve a parking space and related service(s) via another POI service which can be a POI management proprietary service).

S2: C2V Management:

A central parking management system informs approaching vehicles of the presence of different types of parking and provides real time information about the availability of these services (parking and related services). The parking management system may push the information to road users which have contracted the service, or the road user may pull the information from the parking management system.

Receiving vehicles may then reserve a parking space and associated service(s) via another POI service.

5.10.2.4 Implementation scenario flow diagram

The following flow diagram (figure 51) illustrates the described ITS implementation scenarios.

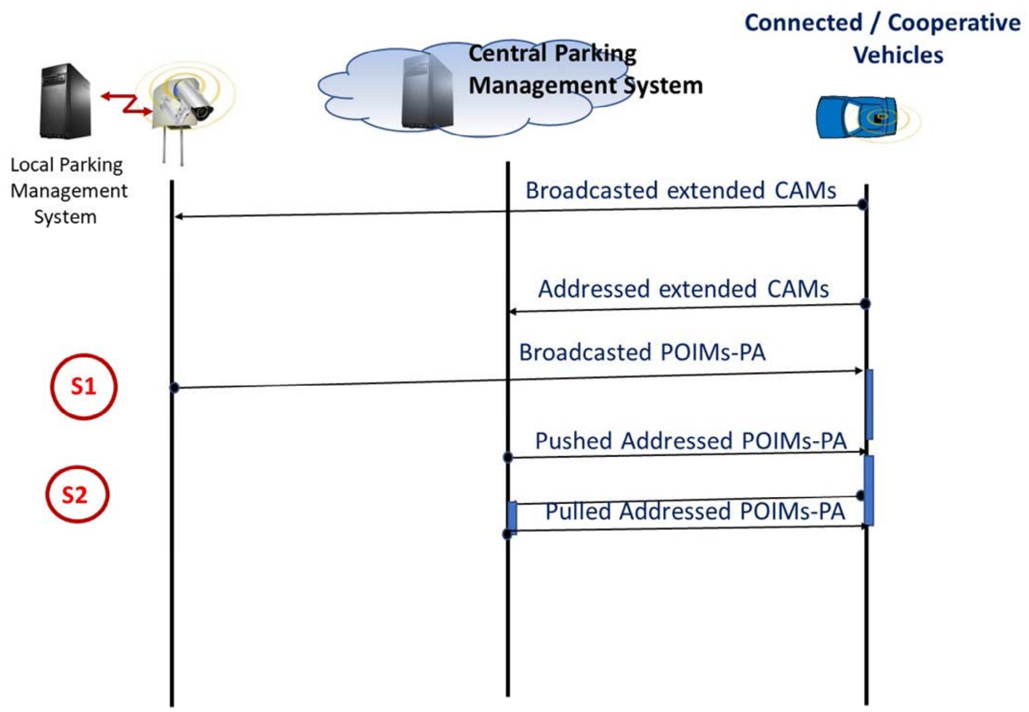


Figure 51: Flow diagram Model 15, CAMs and POIMs-PA addressing and broadcasting

5.10.2.5 Possible implementation scenarios options

ITS-S Scenario 1 option:

Local parking management system, via RSUs broadcasts POIMs-PA informing about parking and associated services and their access conditions.

Receiving vehicles may reserve a parking place/space and associated service(s) information via other POIs management services.

ITS-S Scenario 2 option:

A central parking management system provides information about parking availability and associated services including access conditions. This can be provided to road users on a contractual basis when approaching managed parking places (push mode triggered by the reception of CAMs). This can be also provided on demand of road user (pull mode) when necessary.

5.10.3 Parking Booking Service use case

5.10.3.1 High level description

When booking/reserving a parking space, the user refers to the standard information (e.g. parking space features and other offered parking services) collected at the time of checking the parking availability.

Other information is provided to the user to easy its access to the booked parking place and secure its reservation during a predefined time.

A pre-payment can be necessary to reserve a parking place for a predefined period. Then the final payment can be achieved when the user leaves the parking, based on its stationary time and other services consumption after deduction of the pre-payment.

However, such service may not need to be standardised, only a link (e.g. URL) for parking reservation can be provided leaving the service provider to develop its own proprietary procedures for parking reservation and pre-payment.

5.10.3.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V Management.
- C2V Management.

Possible ITS-S Services:

- Proprietary Parking Reservation Service, and Related POIs Availability standard services.

5.10.3.3 Possible implementation scenarios

S1: I2V Management:

After acquiring information about parking service availability, a subject vehicle may reserve a parking place and associated services via a RSU which is connected to the local management system of the parking. This can be achieved using a Parking Reservation Message addressed to an URL via the RSU.

S2: C2V Management:

After acquiring information about parking service availability, a subject vehicle may reserve a parking space and associated services addressing a reservation message to the central management system.

5.10.3.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

Local parking management system, via RSUs books reserved parking space and associated services according to the received reservation message of the road user.

ITS-S Scenario 2 option:

Central parking management system books reserved parking space and associated services according to the received reservation message of the road user.

5.10.4 Automated Valet Parking use case

5.10.4.1 High level description

At least, the three following AVP scenarios have been demonstrated and some are starting to be implemented:

The automated vehicle is moving alone in the parking to find and park in the parking space which has been assigned by the parking manager while booking it. The booking may have been achieved in the past before accessing the parking or can be achieved when accessing the parking. At the booking time, the subject vehicle receives an updated digital map and the route to follow enabling the automated vehicle or the human driver to navigate in the parking to reach safely its assigned parking space. However, for such parking strategy, the subject vehicle needs to receive constantly an accurate GNSS signal or use other positioning technology to be able to achieve the map matching of its position on the used parking digital map. Once parked, an automated vehicle may leave its parking upon request of its human driver or of its owner in case of SAE level 4 or 5 automated vehicles. This request can be sent via the parking manager or directly to the automated vehicle for example using an SMS.

The automated vehicle is controlled by the parking operator when arriving at the parking entry. This means that the automated subject vehicle receives constantly some manoeuvre instructions (trajectory and velocity) to navigate safely in the parking until reaching its assigned parking space destination. For this purpose, a new facilities layer service, designed for the AVP is needed to ensure interoperability between vehicles and the AVP control system. This means that the parking needs to be equipped with a standard wireless communication network solution enabling the exchange of information between vehicles and the AVP control system. Accurate positioning information of the vehicle should be available for the AVP control system to be capable of controlling the vehicle' trajectory (succession of waypoints) and velocity being indicated by received instructions. For the leaving of the parking, the process is the same in the opposite direction from the assigned parking space to the parking exit. This use case is also known as AVP Type 2 defined in ISO 23374-1 [i.16].

Figure 52 shows the main event flows of AVP Type 2 for parking and retrieving the vehicle. In this case, vehicle's motion is expected to be fully controlled by the AVP Remote Vehicle Operation Sub-System based on information from sensors, including cameras, lidars, radars, etc., installed in the parking facility and operated by the AVP service provider. The AVP Remote Operation Sub-System constructs the environmental model using sensors inputs and periodical status information from the vehicle and provides manoeuvre instruction to the vehicle to steer it along the path, calculated by the AVP Remote Operation Sub-System, to the target position.

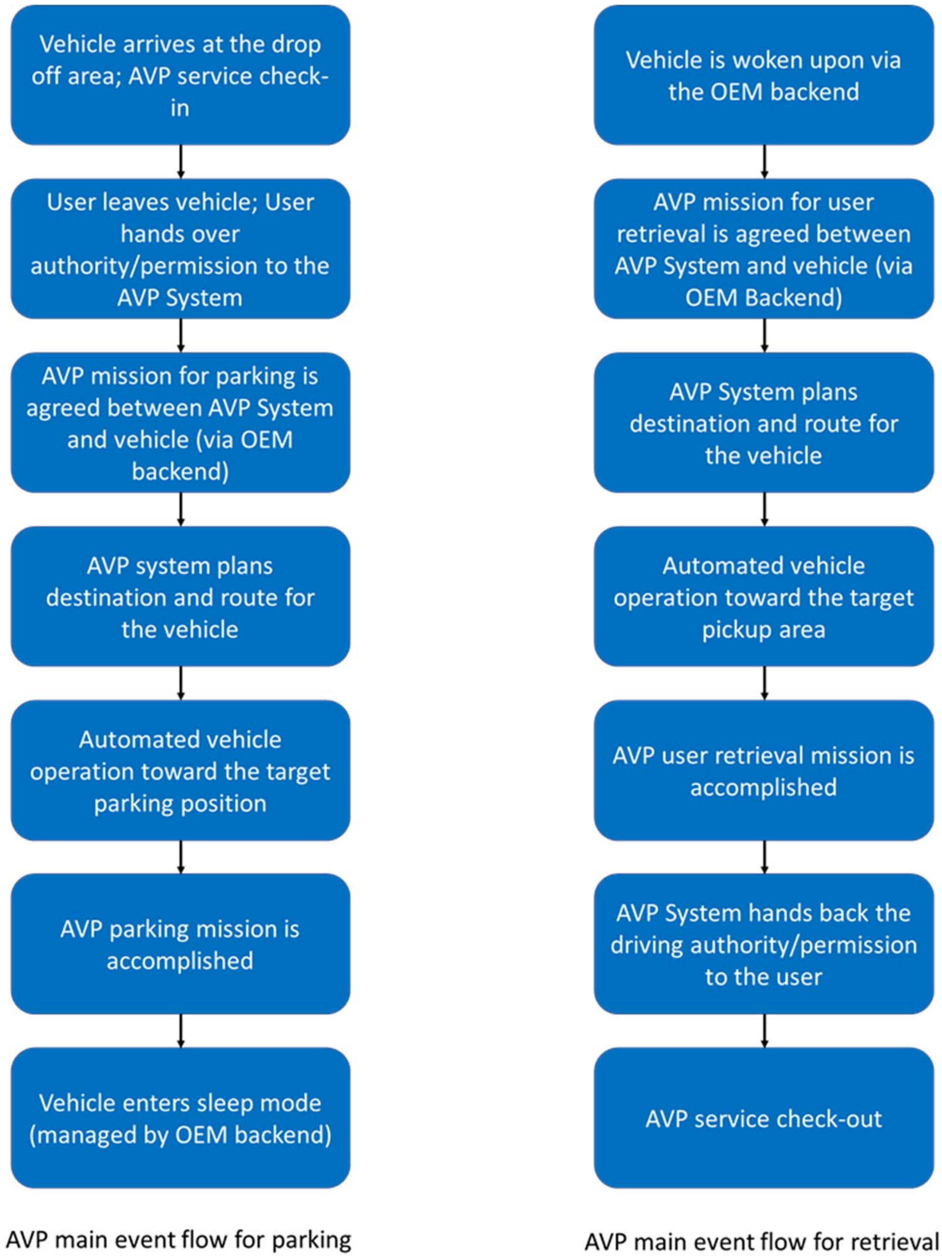


Figure 52: Main event flow of AVP type 2 for vehicle parking and retrieving

A third solution is that the vehicles which have been assigned a parking space go (autonomously or not) to an identified transitory parking place where a parking operator specialised vehicle takes and tows it to its final parking destination. In this case, only a small itinerary can be followed by the subject vehicle before it is taken in charge by the parking operator. For the leaving of the parking a reverse solution exists and consists for the parking operator to fetch and tow the subject vehicle to one transitory parking space and then leaves the subject vehicle to automatically or not exit the parking.

5.10.4.2 Possible ITS architecture and ITS-S services

The following ITS architectures are appropriate for this use case:

- V2V Autonomous.
- Locally managed via I2V.
- Centrally managed via C2V.

Possible ITS-S Services:

- Autonomous perception guided by parking horizontal marking and vertical signalling, + a local digital map.
- C-ITS, or/and long-range communication AVP basic services.
- MCS could be investigated to support such use case.

5.10.4.3 Possible implementation scenarios

S1: V2V Autonomous:

It is the first implementation scenario described here above. The automated vehicle uses its autonomous perception capabilities to locate itself on the digital map of the parking it received before. Then it discovers the itinerary to follow to reach its assigned parking space.

S2: Locally managed via I2V:

The automated vehicle is locally tele-operated by a local parking management system via C-ITS RSUs. Its position can be provided by an augmented GNSS based on local triangulations. The itinerary to follow is provided by the local parking management system (succession of trajectories) until reaching the assigned parking space.

S3: Centrally managed via C2V:

The automated vehicle is centrally tele-operated by a parking management system (type 2 implementation described here above). The itinerary to follow is provided by the central parking management system (succession of trajectories) until reaching the assigned parking space.

5.10.4.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

A standard "parking digital map" needs to be developed.

ITS-S Scenario 2 option:

Augmented GNSS standardization is required at parking level.

ITS-S Scenario 3 option:

Augmented GNSS standardisation is required at parking level.

5.10.5 Parking payment service use case

5.10.5.1 High level description

Booking (Parking service reservation), parking access, and payment are essential steps for the parking services. Automated Valet Parking service as described in clause 5.10.4 requires matching capabilities and interoperability. This requires information exchange between the vehicle and the parking facility at an early stage, even before the service reservation is made. Based on security and trust considerations, the automotive OEM backend plays an important role in such information exchange.

The parking payment process achieved in the scope of the German project SYNCOPARK focusing on Automated Valet Parking (AVP) is a non-exhaustive example of this use case. This payment process is applicable for both conventional and driverless automated valet parking.

However, as for parking reservation, such service may not need to be standardised, only a link (e.g. URL) for parking payment can be provided leaving the service provider to develop its own proprietary procedures for parking payment.

5.10.5.2 Possible ITS architecture and ITS-S services

The following ITS architectures are appropriate for this use case:

- Local payment via I2V.
- Central C2V Payment.

Possible ITS-S Services:

- Proprietary Parking Payment Service and standard Related POIs services.

5.10.5.3 Possible implementation scenarios

The two identified ITS-S service scenarios follow a similar process with the following steps (proposed by German project SYNCOPARK):

- The use case "parking payment" starts when SAEM/POIM-PA is received by the subject vehicle (payment request when approaching the barrier level). Then, if a relevant parking use is confirmed, the parking process executes the following steps (see figure 53):
    1) Vehicle informs driver when receiving SAEM (internal display, mobile phone, etc.).
    2) Driver initiates parking payment process, acknowledging the received payment notification.
    3) Vehicle establishes an IPv6 connection with the parking facility (SAEM IP address and port#) for authentication/payment.
    4) Dedicated peer to peer connection is established (IPv6 tunnel) between the backend and the vehicle via the RSU. CAM are used to track the vehicle position by the RSU for opening/closing the barrier.
    5) Vehicle identifies itself, e.g. sends:
        a) Service provider ID,
        b) User account ID with the service provider.
    6) Parking facility backend verifies account.
    7) Parking facility creates an electronic parking ticket.
    8) When the vehicle passes a defined point, chargeable parking starts.
    9) If the vehicle reaches a barrier, the open barrier process is initiated.
    10) Parking process.
    11) Exiting the parking.
    12) When the vehicle passes a defined point, chargeable parking ends.
    13) Parking facility charges service provider.
- The use case ends when the subject vehicle has left the parking area, and the payment transfer has been completed.

5.10.5.4 Implementation scenario flow diagram

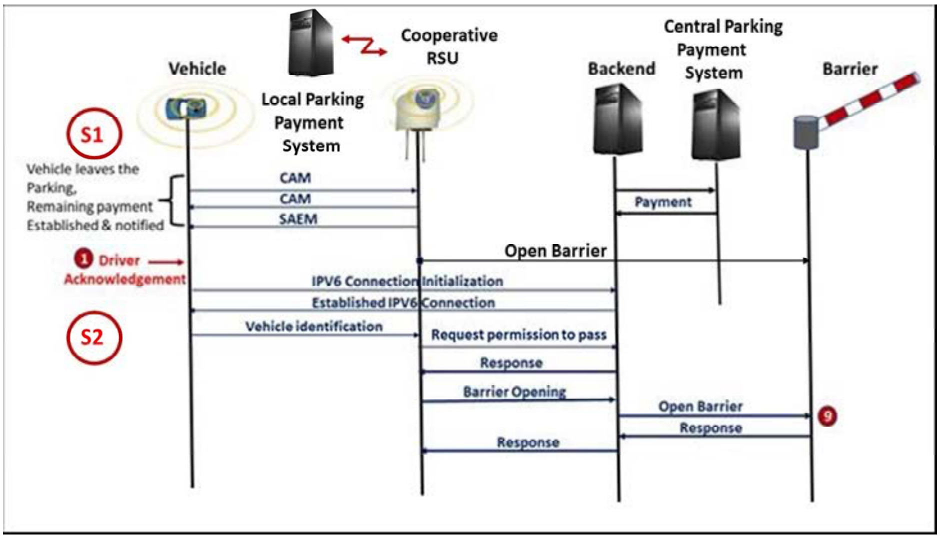


Figure 53: Flow diagram Model 16, combination of addressed and broadcasted standard messages for the support of POIs payment

5.10.5.5 Possible implementation scenarios options

For the two scenarios, the payment can be achieved using several possible means as for tolling payment.

The payment needs to be secured and will have to consider some pre-payment achieved at services reservation time.

The deployment of free flow for highway payment could be considered as well for parking payment (use of the vehicle identification number).

5.10.6 Other POIs use cases

5.10.6.1 High level description

A not exhaustive list of POIs is provided here below:

- Public/Private transport station/Mobility Hub.
- Energy supply station.
- Restaurant.
- Hotel/Motel.
- Commercial/Shopping centre.
- Rest Area.
- Hospital.
- Pharmacy.
- Police station.
- Caravan/Camping site.

- Stadium, Concert Hall.
- Toilets and Public Amenities.
- Attraction Park.
- Etc.

Most of these POIs have related parking POIs which can be privates or publics.

POI Availability service can be very valuable for mobile users during their travels. This is a "mobility application" type which is subject to be deployed in the scope of C-ITS and ITS. Such ITS/C-ITS application can be supported by POISs (Point Of Interest Service) leading to the specification of POIMs (Point Of Interest Messages).

It is then recommended to specify a generic POIS/POIM approach which can be tailored to accommodate the various types of POIs. A possible generic POIM model is represented in figure 54.

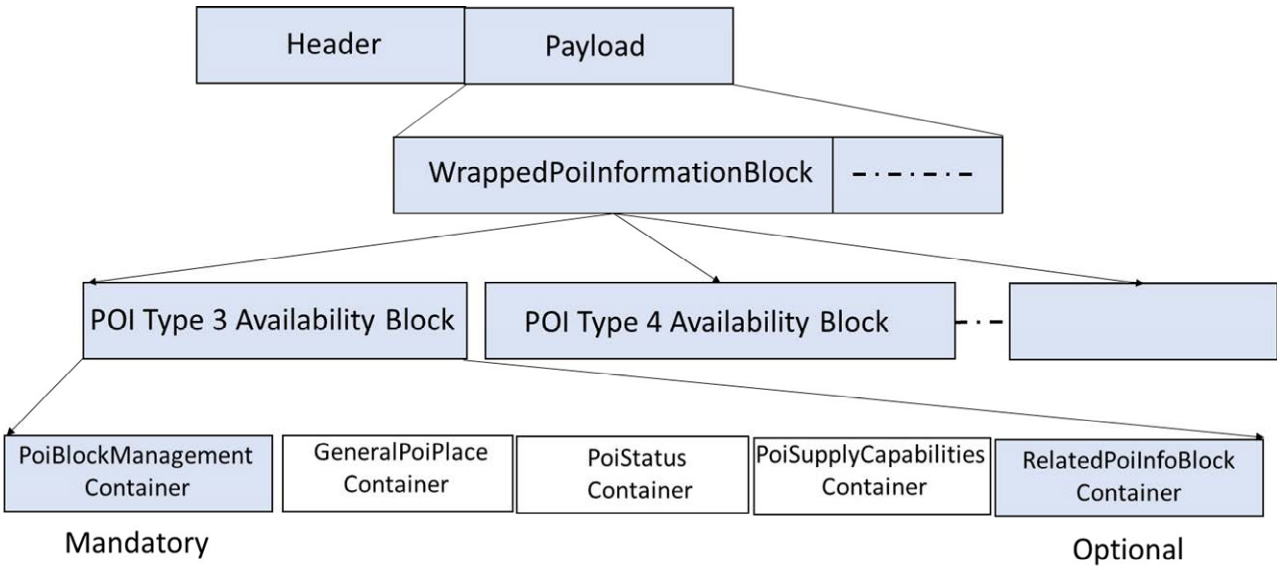


Figure 54: Possible generic POIM model

In such case, mandatory or optional containers dedicated to a particular POI type can be added according to identified POI profiles.

5.10.6.2 Possible ITS architecture and ITS-S services

The two following ITS architectures seem to be the most appropriate ones for this use case:

- I2V Management.
- C2V Management.

Possible ITS-S Services:

- Broadcasted POIS.
- On demand broadcasted (multicast at facilities level) POIS.
- Pushed unicast POIS.
- On demand POS (Pull).

5.10.6.3 Possible implementation scenarios

S1: I2V Management:

Cooperative RSU signals the presence ahead of different types of POIs and provides real time information about the availability of provided services (POIs and related POIs services). Possibility to reserve services and payment conditions are also optionally available.

Receiving vehicles may then reserve a POI service and related POI service(s) via provided link(s).

S2: C2V Management:

A central POIs management system informs approaching vehicles of the presence of different types of POIs and provide real time information about the availability of provided services (POI and related POIs services). The POI management system may push the information to road users which have contracted the service, or the road user may pull the information from the POI management system.

Receiving vehicles may then reserve a POI service and related POI service(s) via provided links.

5.10.6.4 Implementation scenario flow diagram

Flow diagram model 16 in figure 53 is applicable to this use case.

5.10.6.5 Possible implementation scenarios options

S1: I2V Management:

- A RSU may constantly broadcast information at a specified periodic value to approaching vehicles.
- A RSU may constantly broadcast generic information at a specific specified periodic value to approaching vehicles and add information upon received POIM requests (multicast mode at facilities layer).
- A RSU may only broadcast information upon request of approaching vehicles.

S2: C2V Management:

- A central system may push the POI availability information to their users on contractual basis or according to customized algorithms based on received information.
- A central system may respond to customers' specific demand related to POIs services availability (customer pull).

In both cases, POIM and POIM Request messages are necessary.

5.11 Agricultural specific application

5.11.1 ITS service introduction

Tractors and machinery for agricultural and forestry are occasionally needing to use the public terrestrial network and share it with other vehicles. Such agricultural and forestry vehicles are generally huge and slow and may present some risk when moving ahead nearby or in public vehicles' networks.

Moreover, when being at work in fields and forests, several of them may be cooperating to achieve a particular task leading to coordinate their manoeuvres to ensure a safe evolution respecting the task privacy.

Then, they can take profit of the C-ITS/ITS technology and relevant existing standards and in some cases could require the development of new standards.

5.11.2 Task data exchange use case

5.11.2.1 High level description

A job for an agricultural machine is usually described with a task data standardized within ISO 11783-10 [i.17]. Within a ISO XML file relevant data (location, field boundary, guidance references lines, apply rate and others) is stored to define what to do on a field. Working on a field with multiple vehicles is much more efficient if this task data is available for all machines.

5.11.2.2 Possible ITS architecture and ITS-S services

Any vehicle working on a field will offer relevant data of his job (defined within a task) to any other vehicle willing to collaborate. To ensure privacy of task relevant data only after joining a dedicated working group encryption of the data is possible.

- Consequently, in the present document, only V2V cooperation is considered.

Dedicated ITS-S services need to be specified.

5.11.2.3 Possible implementation scenarios options

Because agricultural machines usually working in rural areas, communication infrastructure is not always available. Therefore, a P2P approach will be used. That means every tractor with task data relevant for the job will offer this data to share with anyone willing to work at the same job.

5.11.3 Geo referenced data exchange use case

5.11.3.1 High level description

Working on a field is usually logged based on position data. Besides that, also control of the implement attached to an agricultural machine is often controlled by geo referenced data. This means that on the one hand the amount of applied goods or working intensity (fertilizer, seeding, depth of cultivator…) is defined within a prescription map or/and the area, which is already worked, called coverage map, is stored. Based on this data the amount of applied goods, working state of tools is controlled or even stopped if an area would be worked twice. To work with more than one machine on a field exchange of this georeferenced data is required to be highly efficient. Other than task data, which is usually defined once before the job begins, geo referenced data is gathered while working (coverage data) or could be modify while working (prescription data).

5.11.3.2 Possible ITS architecture and ITS-S services

Any vehicle working on a field will offer relevant georeferenced data of his job to any other vehicle willing to collaborate. To ensure privacy of task relevant data only after joining a dedicated working group encryption of the data is possible. To ensure to have an equal revision of the map data all vehicles will share this data based on a distributed revision management system, enabling every member of the working group to identify status of his mapped data an asking for relevant updates from other to be up-to-dated.

Several ITS architectures are possible to support this use case, especially for the provisioning of geo references and of the local map data.

Dedicated ITS-S services need to be specified.

5.11.3.3 Possible implementation scenarios options

Because agricultural machines usually working in rural areas, communication infrastructure is not always available. Therefore, a P2P approach will be used. That means every tractor with task data relevant for the job will offer this data to share with anyone willing to work at the same job.

5.11.4 Agricultural platooning use case

5.11.4.1 High level description

Agricultural vehicles are often working together in proximity. Typically, this happens in unloading situation where one machine unload goods to a transport vehicle or when two machines doing the same practice, like cultivating the field. To avoid collisions and/or lose of goods during unloading automation of steering and/or speed control is highly welcome within this kind of situation. In difference to automotive platooning ag machinery typically drives next to each other with variable lateral offset and only in few situations (starting a field) behind each other with a fixed lateral offset. Beside that the position offset is based on the desired hit point of the unloading set point and will move to ensure optimal usage of given transport volume.

5.11.4.2 Possible ITS architecture and ITS-S services

The vehicle unloading goods or be in the front position will send desired position for vehicle receiving the goods or following. Based on the amount of unloaded goods the leading vehicle can notch the following vehicle to optimize use of the given transport volume.

- Consequently, in the present document, only V2V cooperation is considered.

Dedicated ITS-S services need to be specified.

5.11.4.3 Possible implementation scenarios options

After being manoeuvred near the leading vehicle the operator of the following vehicle can hand over to automatic. The automatic will stay active as long as the leader or follower will decline automation, or the follower will take over manual control again.

5.11.5 In field safety use case

5.11.5.1 High level description

Agricultural vehicles are often working together in proximity. Also not only being responsible for driving the vehicle but also for taking care for the working process means that the operator could be quite busy. Therefor there is always a certain danger of colliding with other vehicles being in the same field. This means warning the operator of a vehicle that there is another vehicle in proximity moving towards each other could help to avoid dangerous situation.

5.11.5.2 Possible ITS architecture and ITS-S services

Every vehicle will share his position, speed and direction of movement using some agricultural awareness message or the available MCM if judged appropriate.

Consequently, in the present document, only V2V cooperation is considered.

Dedicated ITS-S services need to be specified if existing ones (e.g. CAS, MCS) are not retained as appropriate to support such use case.

5.11.5.3 Possible implementation scenarios options

Receiving this kind of messages will enable every vehicle to judge if there are other participants moving around in proximity, and direction that a collision could be possible. Based on this a warning message could be display to the operator to make him aware of this situation.

5.11.6 Agricultural work awareness use case

5.11.6.1 High level description

Agricultural vehicles are often working next to public roads. This could affect in certain situation road users by dust or particles thrown into the air by agricultural working process. To enable road users to reduce speed or other measures to react on potential harmful situation the agriculture machine could sent on regular interval an awareness message enabling road users to judge by their own if that is from relevance for them.

5.11.6.2 Possible ITS architecture and ITS-S services

Every vehicle in the field will share his position, speed and direction of movement using some agricultural awareness message or an extension of the CAM to agricultural vehicle types.

Consequently, in the present document version, only V2V cooperation is considered.

Dedicated ITS-S services need to be specified if existing ones (e.g. CAS, MCS, etc.) are not retained as appropriate to support such use case.

5.11.6.3 Possible implementation scenarios options

Receiving this kind of messages will enable every vehicle to judge if there is a general potential of danger coming from this vehicle not being on the road and if that could be verified by other sensors (e.g. camera detecting dust). Based on that the operator could be warned or the automation system can react on this.

5.12 Integration of C-ITS in Public Warning System

5.12.1 ITS service introduction

Natural disasters and the thousands of casualties they usually cause have often made the headlines in the past years. A milestone event in this field was the Indian Ocean tsunami that happened in December 2004. This event raised the question of how to improve the protection of the population and prevent so many deaths. In fact, the main answer relies in the fast distribution of the information: information about the best behaviour to adopt in case of a disaster, and more importantly, information about the imminent arrival of a disaster and evacuation orders. Therefore, many actions have been started by the public authorities to reduce the damages and the number of casualties.

When a disaster occurs, the national or local authorities need to provide information to the citizens regarding the impact of the disaster including precautions that need to be taken by the citizens to increase their safety (see ETSI TS 102 182 [i.18]). The information provided by the authorities to the citizens is delivered to the area(s) where the incident happens, that can be limited to a small area(s) and up to the whole country. Since its Release 8, 3GPP has started the specification of a Public Warning System (see ETSI TS 122 268 [i.5]) allowing for direct warnings to be sent from national or local authorities to mobile users on devices capable of displaying a text-based and language-dependent Warning Notification. However, the combination of different technologies, including IoT and C-ITS communication means, could improve drastically the efficiency of the alerting global system by increasing the coverage of the existing network to reach more people in a faster way. People in vehicles usually do not watch TV and may not be listening to the radio.

The information in next clauses is derived from use case PWS1 in ETSI TR 103 582 [i.8].

5.12.2 Natural disaster alert use case

5.12.2.1 High level description

The use case begins when a disaster happens, see ETSI TS 122 268 [i.5], ETSI TR 103 582 [i.8]:

1) Local Emergency Management Authority (LEMA) wants to inform the citizens about the emergency/disaster.

2) The authority server(s) connected directly to an IoT/Road operator network or to a public communication network sends the information instantaneously with no delay to the service platforms responsible for the designated areas. These networks ensure secure communications where no intruders can provide false public warning information via the network.

3) The devices and platforms receiving the public warning information forwards it to other IoT devices or ITS-Stations based on their capabilities. A V-ITS-S or R-ITS-S receiving the message can also forward it to neighbouring ITS-S (multi-hop forwarding). The warning passing through the IoT network could also reach public connected screens (billboards, bus stop displays, etc.).

The V-ITS-S translates the received message into other notification formats towards the vehicle driver. Examples include the display of the messages on the on-board screen, or even speak out the message, triggering of alarms/buzzers, blinking of lamp/led, etc. No acknowledgment is required for receiving these messages.

Figure 55 illustrates the natural disaster alert use case.

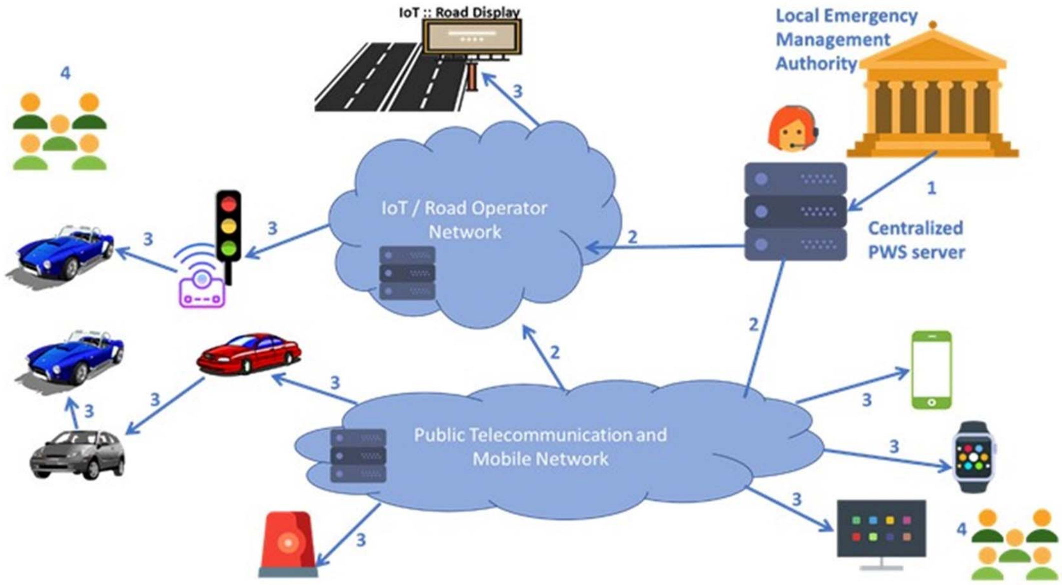


Figure 55: Natural Disaster Alert use case

5.12.2.2 Possible ITS architecture and ITS-S services

Local Emergency Management Authority (LEMA): In case of PWS, it specifies the area/location where the information should be sent. The method for communicating the information as language, sound, light, etc. can be provided based on regulatory requirements.

Communication networks/ service provider: connecting the authority server capable of transporting the public warning information instantaneously to all the devices (mobile phones, IoT, ITS-S) in the designated areas, ensuring the information needed is up to date and in-line with the regulation and authority preferences, as well as compatibility between the connected communication network and the devices. It provides a reliable, consistent, and secure means for transporting the information.

Receiving device: This is for example a V-ITS-S. It can detect duplicated PWS messages and discarding them. It presents the public warning information to the driver, conveying one or more types of media (text, voice, sounds, light alarms). But, when possible, it relays the information in an ad-hoc manner to other vehicles nearby. The information can be encapsulated into an extended DENM or be carried as a payload in a dedicated new C-ITS message.

5.12.2.3 Use case analysis

This use case introduces V2X communications as another media to propagate alerts in the Public Warning Systems. This use case requires that ITS-S can receive and decode the alert (either from the public network or from the road operator network), present it to the user of the ITS-S and when possible, transfer the message as a multi-hop message to neighbouring ITS-S using an extended DENM or a dedicated C-ITS message. The impacts would be on the infrastructure e.g. road operators, city operators, system integrators, but also on the applications and services provided by on-board units.

V2X communications, and more particularly V2V communications, are interesting in this case because they provide techniques that can work even during severe conditions of disaster situations when the network infrastructure is damaged. For example, the natural disasters evaluated in WMAPS 2011 paper [i.19] are earthquake and flash flooding, together with sabotage scenarios such as power outage and network random failures. It is sufficient that one ITS-S receives the alert: it is then capable to distribute the information to other ITS-S and reach a higher number of citizen road users.

5.13 Vehicle lawful interception

5.13.1 ITS service introduction

The following three ITS applications can be considered:

- The automated vehicle is tele-operated by a supervision system during normal operation (no safety concern). The vehicle is remotely controlled by a human operator or by a relevant program based on uploaded information about the surrounding mobile objects (vehicles or VRUs).
- The automated vehicle (level 4 or 5 without a driver in it) is tele-operated by a supervision system in case of emergency (the vehicle cannot safely proceed in an automated mode). The vehicle needs to notify this status to the remote supervisor which takes over the driving tasks.
- The automated vehicle is intercepted by a relevant authority for inspection (stolen vehicle, drug or other prohibited goods transportation, suspected terrorist attack, etc.). A vehicle inspection request is sent to the supervision system which acts on the automated vehicle to immobilize it.

Generally, some public agents (e.g. police) will ask the vehicle to stop for an inspection. Public agents will be then facing two different possible situations:

- The vehicle is driven by a human. In this case, either the human is respecting the stop' request or he is not, so forcing the passage.
- The vehicle is in an automated mode and consequently needs to understand the stop sign provided by the authority agent. The automated vehicle needs also to be able to react to the stop' request (not having been modified to ignore it). But if the police agent is going to ask the vehicle driver/occupant to stop not being aware of its automated state, the vehicle has automatically to stop, not continuing its travel.

So, generally, it is necessary to digitally communicate the need to stop/being inspected to a vehicle that is not necessarily human-driven or eventually force this vehicle to stop by acting on it.

5.13.2 Operational safety management use case

5.13.2.1 High level description

For automated vehicles of SAE levels 4 and 5 moving without a driver in them, it is mandatory to have the possibility to tele-operate them from a central supervision system in case of operational safety problems and other situations identified here above in clause 5.13.1.

As such central supervision system do not have in general the monitored local environments perception, they need to rely on information provided by all static and mobile objects which can share such local perception. This is achieved collecting and using all standardized messages and in particular the Collective Perception Messages.

Such tele-operation is possible only if satisfying well identified minimum performance requirements especially at the end-to-end latency time level. If such minimum performance requirements are not achievable by existing long-range networks, local supervision systems connected to RSUs via Local Area Networks could be used.

Figure 56 illustrates the operational safety management use case.

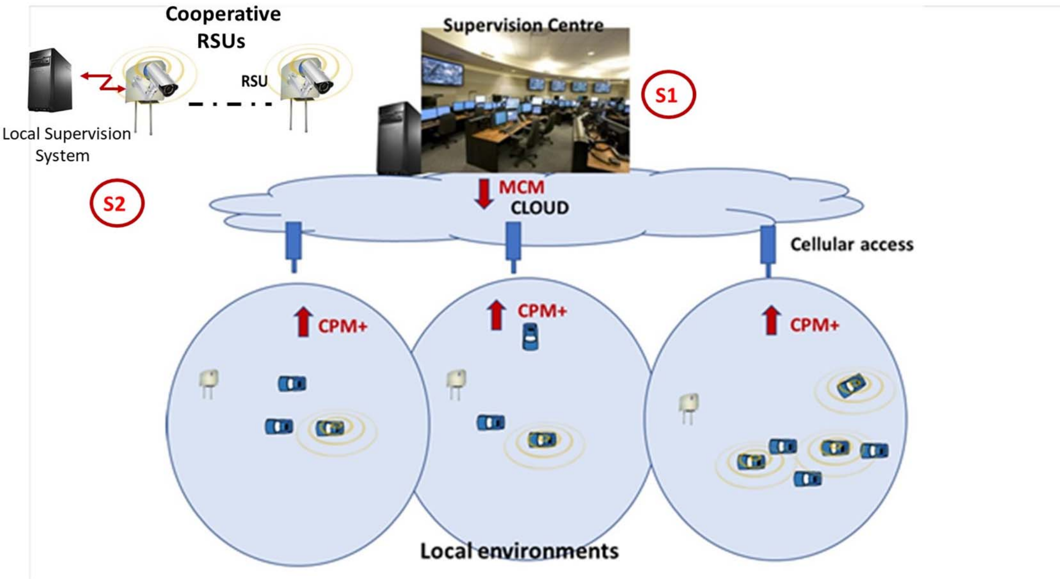


Figure 56: Operational Safety management use case

5.13.2.2 Possible ITS architecture and ITS-S services

The following ITS architectures seem to be the most appropriate ones for this use case:

- I2V Supervision.
- C2V Supervision.

Possible ITS-S Services:

- All standard basic services enabling the transfer of local information to the supervision system.
- MCS for the vehicles' tele-operation.

5.13.2.3 Possible implementation scenarios

S1: I2V Management:

Based on real time local environment information acquisition, a local supervision system has the capability of tele-operating a SAE level 4 or 5 automated vehicle without a driver in it in case of an operational safety detected problem. The local supervision system needs to have the capability to identify the RSU which can be used for this teleoperation.

S2: C2V Management:

Based on real time local environment information acquisition, a central supervision system has the capability of teleoperating a SAE level 4 or 5 automated vehicle without a driver in it in case of an operational safety detected problem.

5.13.2.4 Possible implementation scenarios options

ITS-S Scenario 1 option:

All involved RSUs collect local information from exchanged messages and transfer them to the local supervisor.

The local supervisor can use the MCS "prescription concept" to directly act on the manoeuvre of the subject vehicle and other relevant cooperative vehicles which could be impacted by a risk of collision. Broadcasted MCMs are used.

ITS-S Scenario 2 option:

All static and mobile objects which have an autonomous perception collect local information which are communicated in real time to the central system using unicast links. If the central system detects an operational safety problem, this one can tele-operate the concerned subject vehicle and other relevant vehicles to avoid collision. This can be done using MCMs addressed to relevant vehicles.

5.13.3 Stolen vehicle use case

5.13.3.1 High level description

The proposed system architecture can be used for SAE level 4 & 5 automated vehicles. However, such approach can be extended to all release 2 cooperative vehicles even when human driven.

In case of a human driven cooperative vehicle, there are two possibilities for a stolen vehicle interception:

- Taking control of the vehicle once identified. This can be achieved by a human police officer having a specific device which may instruct the subject vehicle to safely stop. It may also be achieved by a Roadside unit or a central supervisor which has the authority (specific permission) to achieve such action when the subject vehicle is identified (for example via its registration plate).
- Being intercepted by a police officer which is informed that the subject vehicle has been stolen.

Two steps are necessary for the interception of a stolen vehicle:

- The vehicle needs to know that it has been stolen. This can be communicated to the vehicle by an RSU or a central system after a declaration by the owner to the relevant police service.
- Then, a stolen vehicle may communicate its stolen state by broadcasting extended CAMs providing such state. This can lead to a police interception when detecting this extended CAMs.

Figure 57 illustrates the stolen vehicle use case.

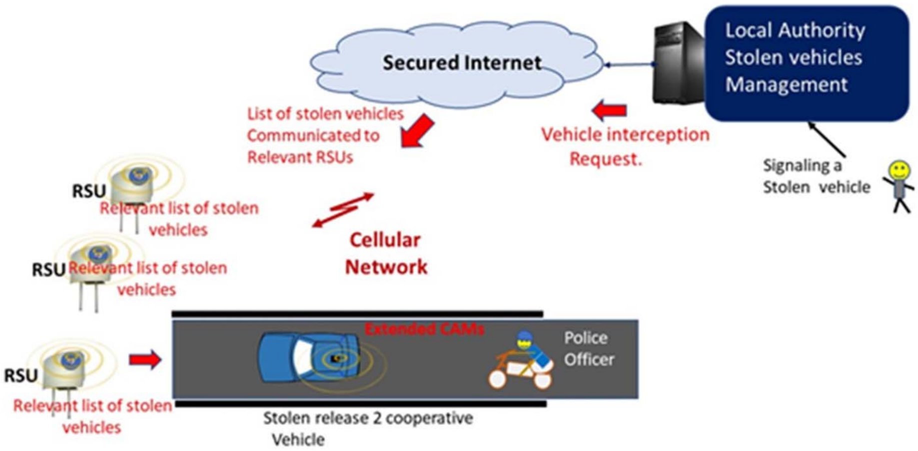


Figure 57: Stolen Vehicle management use case

5.13.3.2 Possible ITS architecture and ITS-S services

The following ITS architectures seem to be the most appropriate ones for this use case:

- I2V and V2V.
- C2V and V2V.

Possible ITS-S Services:

- Extended DENS.
- Extended CAS.
- MCS.

5.13.3.3 Possible implementation scenarios

S1: I2V and V2V:

Relevant RSUs broadcasts the list of stolen vehicles (e.g. indicating their registration numbers). If the subject vehicle recognizes its registration number, it transits in a "stolen state" which is signalled in the extended CAMs. Then a police officer which is passing by can detect that the vehicle is a stolen vehicle and then can intercept it using MCS.

S2: C2V and V2V:

Relevant central system addresses a stolen vehicle to signal it its "stolen state". Then, the stolen vehicle transits to a "stolen state" which is signalled in the extended CAMs. A passing by police officer may then detects the stolen vehicle and can intercept it using MCS.

5.13.3.4 Possible implementation scenarios options

For the two scenarios, the process is similar:

- Extended DENMs can be used to signal to a subject vehicle that this one is a "stolen one".
- Extended CAMs can be used to signal to relevant authorities that the subject vehicle is in a "stolen state".

MCM "prescriptive concept" is used by the relevant authority to stop and/or lead the stolen vehicle (e.g. follow-me) to a relevant parking place.

5.13.4 Police interception use case

5.13.4.1 High level description

Relevant police authorities may require the interception of vehicles whatever the legal cause and associated risk (user road safety, user mobile asset protection, or citizen health/security). In a human driven situation, it is the responsibility of the human driver to react to such requirement. But in an automated situation, it is the responsibility of the vehicle to respond to such requirement.

Figure 58 illustrates the police interception use case.

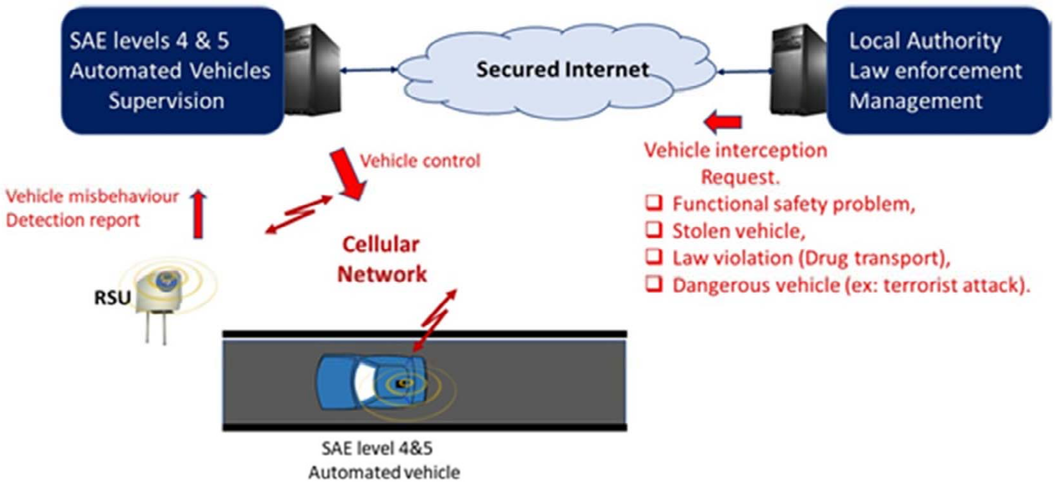


Figure 58: Vehicle police interception use case

5.13.4.2 Possible ITS architecture and ITS-S services

The following ITS architectures seem to be the most appropriate ones for this use case:

- P2V/V2V.
- I2V.
- C2V.

Possible ITS-S Services:

- MCS.

5.13.4.3 Possible implementation scenarios

S1: P2V/V2V:

A police release 2 cooperative vehicle/device broadcasts MCMs to relevant vehicles (subject and targets) requiring the stop or/and achieving specific manoeuvres necessary for the safe interception of the subject vehicle.

S2: I2V:

Release 2 cooperative RSU broadcasts MCMs to relevant vehicles (subject and targets) requiring the stop or/and achieving specific manoeuvres necessary for the safe interception of the subject vehicle.

S3: C2V:

A relevant central system addresses MCMs to relevant vehicles (subject and targets) requiring the stop or/and achieving specific manoeuvres necessary for the safe interception of the subject vehicle.

5.13.4.4 Possible implementation scenarios options

The MCS "prescriptive concept" is used.

6 Conclusions

6.1 Introduction

Clause 6.2 provides a summary of possible impacts on existing ETSI ITS standards which are currently available in the published release 1 set, considering the extension of the basic set of ITS applications which are proposed in the present document. Moreover, in clause 6.3, a summary of the proposed release 2 and beyond basic set ITS applications and its associated use cases is provided.

6.2 Impacts on release 2 standards

Optional containers, new Data Frames and new Data Elements could be added in release 2 messages (version 2). Possible evolutions can be provided in possible implementation scenarios at ITS applications and use cases level.

6.3 Summary of the release 2 basic set of ITS applications and associated use cases

The present document does not include an exhaustive list of ITS applications and use cases which need to be addressed for the deployment of automated vehicles. It is only a first proposal which can be extended according to new emerging needs. Table 1 provides a summary of services/applications and use cases which have been considered.

NOTE: An application/use case may be developed to support independently or simultaneously several services. For example, increasing the traffic fluidity (traffic management) may have an impact on the reduction of environmental pollution (environmental protection).

Table 1: Summary of the basic set of applications and its associated use cases

ITS Services	Basic Set of ITS Applications and associated use cases	Main targeted ITS Service category	Comments
Partial and high automation	Hazardous location notification - vehicle assistance	User road safety	
	Cooperative Adaptive Cruise Control (C-ACC)	Traffic Management	Part of longitudinal automation
	C-ACC string	Traffic Management	
	Cooperative Adaptive Emergency Brake System (C-AEBS)	User road safety	Automated action on the vehicle secondary braking system
	Advanced Pre-crash sensing	User road safety	Collision impacts mitigation
	Cooperative Active Lane Keeping (C-ALK)	User road safety	Part of longitudinal automation
	Cooperative Intelligent Speed Adaptation (C-ISA)	User road safety and traffic management	See CEN Contextual Speed Adaptation
	Cooperative Tyre Pressure Adjustment System	User road safety and environmental protection.	TPMS mandatory at E.U level. Required for vehicle operation
	Cooperative Vehicle Energy Critical Situation Assistance	Mobility assistance	Required for vehicle operation
	Infrastructure support for ADS	User road safety and traffic management.	
CCAM Augmented Perception	Perception of a non-connected vehicle at an intersection	User road safety	
	Perception of a non-connected stationary vehicle at the top of a slop	User road safety	
	Advanced non-connected slow vehicle warning	User road safety	

ITS Services	Basic Set of ITS Applications and associated use cases	Main targeted ITS Service category	Comments
	V2V/I2V non-connected VRU perception	User road safety	
	Perception into a tunnel		
	Perception of traffic when merging		
Vehicles' coordination	Cooperative Lane Merging (CLM)	User road safety and local traffic management	
	Cooperative Lane Change (CLC)	User road safety and local traffic management	
	Advanced Cooperative ACC (string) (AC-ACC S)	Local traffic management	
	Truck platooning management	Traffic management and environmental protection	
	Toll Plaza Guidance		
	Cooperative transition control	User road safety	
Multi-Car Collision avoidance	V2V risk analysis and avoidance	User road safety	
	Advanced signal violation warning	User road safety	
	Advanced wrong way driving warning	User road safety	
Intersection crossing assist	Advanced Intersection Collision Warning (AICW).		
	Not controlled intersection	User road safety and local traffic management	
	Traffic light-controlled intersection - Priority vehicles management	User road safety and local traffic management	
	Optimized traffic light information from V2I	User road safety and local traffic management	
	Automated GLOSA (A-GLOSA)	User road safety and local traffic management	
	Automated GLOSA with negotiation	User road safety and local traffic management	
	Railway level crossing	User road safety	
	Other intersection/area crossing	User road safety	
advanced warning and information, VRUs protection	Advanced Slow Vehicle Warning (ASVW)	Traffic management	May include VRUs vehicles
	Filtering motorcycle	VRU road safety	
	Overtaking motorcycle	VRU road safety	
	Overtaking motorcycle and turning vehicle	VRU road safety	
	Turning vehicle with PTW in the blind spot	VRU road safety	
	VRU presence awareness	VRU road safety	
	VRU collision warning	VRU road safety	
	VRU Brake and Steering intervention	VRU road safety	
	VRU safety beacon	VRU road safety	
	VRU complex interaction	VRU road safety	
	Interactive VRU crossing	VRU road safety	
	Extended cluster management	VRU road safety	
Dynamic Navigation	Detour Management	Local & Global traffic management	Can be used for environmental protection to reduce the traffic pollution in some protected areas
Contextual, dedicated corridor management	Corridor dedicated to an emergency vehicle, rescue/recovery, prioritized/safety vehicle	Citizens' protection, local & global traffic management	

ITS Services	Basic Set of ITS Applications and associated use cases	Main targeted ITS Service category	Comments
	Active highway corridor for electrical vehicles reloading	Local and global traffic management, Energy supply assistance	
	Corridor dedicated to other priority vehicles	Local and global traffic management	Public transport/car' pooling for environmental protection. Winter interventions to maintain the road infrastructure operational
	Hard Shoulder Running	Local and global traffic management	
	Roadwork warning (long-term)	Local and global traffic management	Roads access restrictions. Related to detour management
POIs Management	Parking Availability Service	Mobility assistance	Can be considered as a generic example for other types of POIs availability services
	Parking booking service	Mobility assistance	
	Automated Valet Parking	Mobility assistance	
	Parking payment service	Mobility assistance	
	Other POIs	Mobility assistance	POIs related to the vehicle' operation and users' mobility
Agricultural specific use cases	Task data exchange	Mobility assistance and safety	
	Geo referenced data exchange	Mobility assistance and safety	
	Agricultural platooning	Mobility assistance and safety	Synchronization between several agricultural vehicles according to tasks to achieve
	In-field safety	Mobility assistance and safety	
	Agricultural work awareness	Mobility assistance and road safety	
Integration of C-ITS in Public Warning System	Natural disaster alert	Mobility assistance and citizen protection	Related to emergency corridor
Vehicle lawful interception	Operational safety	Road safety	
	Stolen vehicle	Road safety and user mobile asset protection	
	Police interception	Road safety, citizen protection, legislation respect	

From the analysis of these applications and use cases, necessary extensions to the existing ITS standards (e.g. CAM, DENM, VAM, etc.), and to the ones under development (CPM, MCM) have been identified. New standards may need to be developed as well but further investigations are needed.

Annex A: Bibliography

M. Wetterwald, C. Bonnet, D. Câmara, S. Grazzini, J. Fenwick, X. Ladjointe, J.-L. Fondere: "Integrating Future Communication Technologies for the Downstream Component of Public Warning Systems", International Journal on Advances in Networks and Services, 2012 vol 5 nr 3&4, pp 189-197.

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