Use Case Implementation Description (UCID)

5GAA Automotive Association
Technichal Report

CONTACT INFORMATION:

Lead Coordinator – Thomas Linget
Email: thomas.linget@5gaa.org

MAILING ADDRESS:

5GAA c/o MCI Munich
Neumarkter Str. 21
81673 München, Germany
www.5gaa.org

VERSION:	1
DATE OF PUBLICATION:	12.04.2021
DOCUMENT TYPE:	Technichal report
CONFIDENTIALITY CLASS:	P (Public use)
REFERENCE 5GAA WORKING GROUP:	Working Group 1
DATE OF APPROVAL BY 5GAA BOARD:	19.03.2021

Contents

Foreword

This Technical Report has been produced by 5GAA.

The contents of the present document are subject to continuing work within the Working Groups (WG) and may change following formal WG approval. Should the WG modify the contents of the present document, it will be re-released by the WG with an identifying change of the consistent numbering that all WG meeting documents and files should follow (according to 5GAA Rules of Procedure):

x-nnzzzz

(1) This numbering system has six logical elements:

(a) x: a single letter corresponding to the working group:

where x =

T (Use cases and Technical Requirements)

A (System Architecture and Solution Development)

P (Evaluation, Testbed and Pilots)

S (Standards and Spectrum)

B (Business Models and Go-To-Market Strategies)

(b) nn: two digits to indicate the year. i.e. ,17,18 19, etc

(c) zzzz: unique number of the document

(2) No provision is made for the use of revision numbers. Documents which are a revision of a previous version should indicate the document number of that previous version

(3) The file name of documents shall be the document number. For example, document S-160357 will be contained in file S-160357.doc

1 Scope

This report presents the results of the 5GAA work item Use Case Implementation Description (UCID) [1]. The objectives of the work item are to develop:

- Use Case Implementation Descriptions (UCIDs) that meet/realise the service level requirements (SLRs) [11] for the use cases:
    - Cross-Traffic Left-Turn Assist (LTA)
    - Emergency Brake Warning (also referred to Electronic Emergency Brake Light Warning or 'EEBL Warning')
    - Traffic Jam Warning and Route Information
- Overarching application system implementation specifications combining the respective use case implementation specifications, including potential interfaces to the network and security layers. Note that this is also the template and foundation for developing future-oriented use cases (like Group Start) that are developed for example in the context of the NRV2X xWI.

2 References

[1] 5GAA WG1 T-200051, Use Cases Implementation Descriptions (UCID) work item description

[2] 5GAA WG2, V2X Application Layer Reference Architecture, available online at https://5gaa.org/news/v2x-application-layer-reference-architecture/

[3] C-ITS IP Based Interface Profile Version 1.7.0 or later versions, available online at https://www.c-roads.eu/platform/documents.html (Note: document contains the full profile for backend communication, including AMQP profiling)

[4] Advanced Message Queuing Protocol (AMQP), available online at https://www.amqp.org/

[5] C2C-CC, Triggering Conditions and Data Quality Traffic Jam CAR 2 CAR Communication Consortium, available online at https://www.car-2-car.org/fileadmin/documents/Basic_System_Profile/Release_1.5.1/C2CCC_RS_2007_TrafficJam.pdf

[6] C2C-CC, Triggering Conditions and Data Quality Dangerous Situation CAR 2 CAR Communication Consortium, available online at https://www.car-2-car.org/fileadmin/documents/Basic_System_Profile/Release_1.5.1/C2CCC_RS_2003_DangerousSituation.pdf

[7] 5GAA, C-ITS Communication System Profile Using Cellular Uu, available online at https://5gaa.org/wp-content/uploads/2020/02/5GAA_S-180175_TS_C-ITS_Comm_System_Profile_Uu_v1.0.pdf

[8] ETSI EN 302 637-2 V1.3.1 (2014-09), Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service

[9] ETSI EN 302 637-3 V1.2.1 (2014-09), Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralised Environmental Notification Basic Service

[10] SAE J2735_202007, V2X Communications Message Set Dictionary

[11] 5GAA WG1 T-200111 Technical reports C-2X Use Cases and Service Level Requirements Vol I V3.0

[12] ETSI TS 103 723 V1.1.1 (2020-09), Intelligent Transport Systems (ITS); Profile for LTE-V2X Direct Communication

3 Abbreviations

AMQP	Advanced Message Queuing Protocol
AVP	Automated Valet Parking
BSM	Basic Safety Messages
CAM	Cooperative Awareness Message
DENM	Decentralized Environmental Notification Message
EEBL	(Electronic) Emergency Brake (Light) Warning (EEBL),
HV	Host Vehicle
IF	Interchange Function
IMA	Intersection Movement Assist
IOO	Infrastructure Owner Operator
IVI	In-Vehicle-Information
JSON	JavaScript Object Notation
LTA	Cross-Traffic Left-Turn Assist
MNO	Mobile Network Operator
MQTT	Message Queuing Telemetry Transport
OEM	Original Equipment Manufacturer
OEM App	Original Equipment Manufacturer Application
OEM AS	Original Equipment Manufacturer Application Server
PRR	Packet Reception Ratio
REST	Representational state transfer
RO	Road Operator
RTA App	Road Traffic Authority Application
RTA AS	Road Traffic Authority Application Server
RTO	Road Traffic Operator
RTTI	Real-Time Traffic Information
RV	Remote Vehicle
SDO	Standards Developing Organisations
SLR	Service Level Requirements
SP App	Service Provider Application
SP AS	Service Provider Application Server
TJW	Traffic Jam Warning
UC	Use Case
UCID	Use Case Implementation Description

V2I	Vehicle-to-Infrastructure
V2N2I	Vehicle-to-Network-to-Infrastructure
V2N2V	Vehicle-to-Network-to-Vehicle
V2V	Vehicle-to-Vehicle
V2X App	Vehicle-to-everything Application
V2X AS	Vehicle-to-everything Application Server
VRU	Vulnerable Road User

4 Introduction

In this chapter the different communication entities are introduced and briefly described.

Subsequent chapters describe implementation options for the different entities and their communication channels in more detail.

The below application layer reference architecture has been agreed in 5GAA (WG2 TR A-200094 'V2XSRA' [2]) and will be used for the UCIDs.

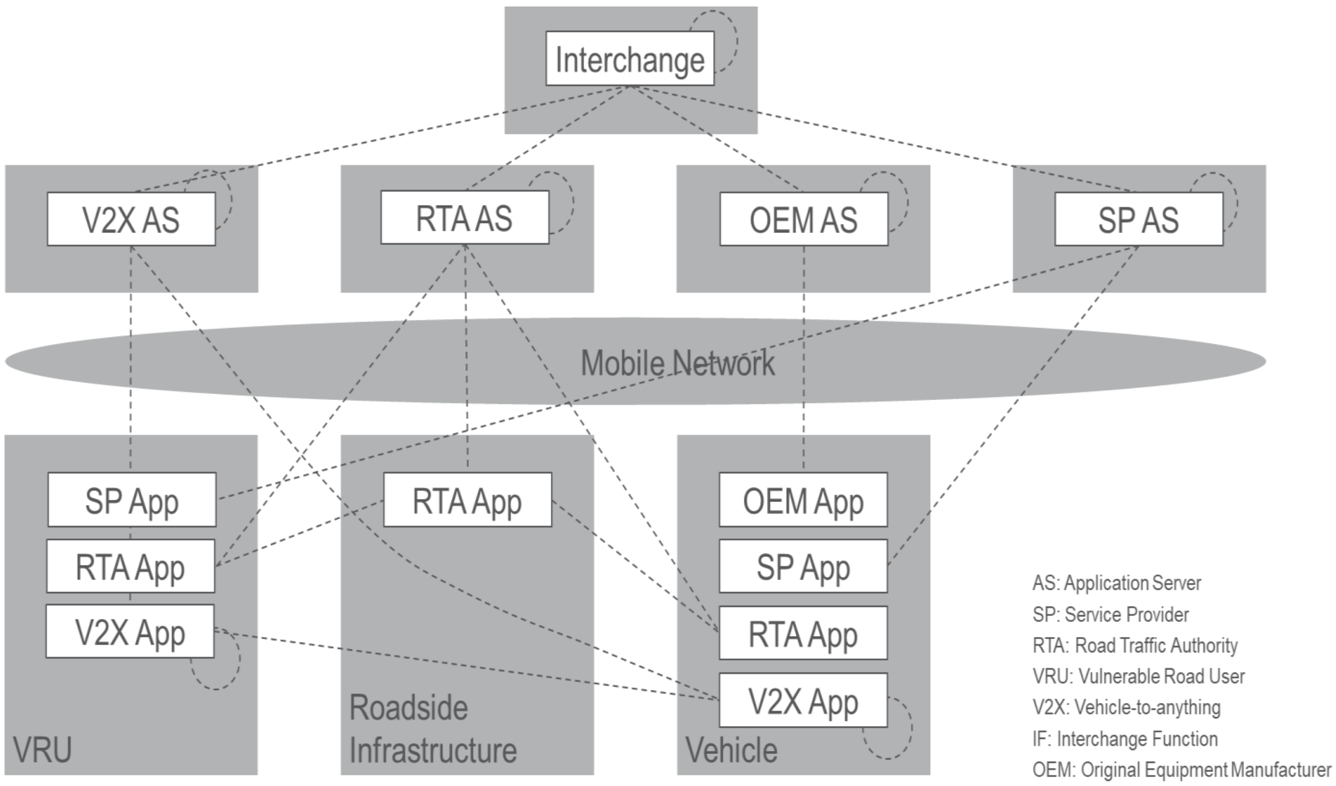

Figure 1 V2X application layer reference architecture

Note on Figure 1: The connection between RTA AS and RTA App in Roadside Infrastructure can be either via mobile network or fixed network.

The following functional components are included in the V2X Application Layer Reference Architecture:

Vehicle-to-everything Application Server (V2X AS)

The V2X AS routes C-ITS messages between V2X Apps (using cellular communication) and disseminates C-ITS messages within a geographical area.

Vehicle-to-everything Application (V2X App)

The V2X App sends and receives C-ITS messages to and from the V2X AS (using cellular communication). Furthermore, the V2X App sends and receives C-ITS messages to and from other V2X Apps.

Original Equipment Manufacturer Application Server (OEM AS)

The OEM AS offers services to the vehicles manufactured by the OEM and to its drivers and passengers. The services could be, for example, telematics, infotainment, navigation, security certificate handling and traffic-related safety services.

Original Equipment Manufacturer Application (OEM App)

The OEM App integrates services offered by the OEM AS into vehicles. These services are available to the driver and passengers via the vehicles' human-machine-interface (HMI).

Road Traffic Authority[1] Application Server (RTA AS)

The RTA AS offers services for traffic efficiency and safety to vehicles. These types of services are partly driven by legislation. Furthermore, RTA AS manages Road Side Infrastructure, such as variable road signs, traffic lights and video surveillance cameras.

Road Traffic Authority Application (RTA App)

The RTA App integrates the services offered by RTA AS into vehicles or into Road Side Infrastructure. Furthermore, RTA App may exchange traffic efficiency and safety information with other RTA Apps.

Service Provider Application Server (SP AS)

Various providers offer different services to, among others, vehicles and VRUs. The services may be of a professional nature, such as fleet management, navigation, traffic-related safety information, or personal services like infotainment. Although these services are delivered from SP ASs to the vehicles, the services may still be authorised and controlled by the OEM AS.

Service Provider Application (SP App)

The SP App integrates the services offered by SP AS into vehicles and VRUs. These services are available to the driver and passengers via the vehicles' human-machine-interface (HMI) and to VRUs.

Interchange Function (IF)

Given the large number of different Road Traffic Authorities in the world, Interchange Functions are needed to scale up and secure the message exchanges between RTA ASs, OEM ASs and SP ASs.

Vulnerable Road User (VRU)

Typically, a handheld device, or a smartphone with the needed capabilities or applications.

Roadside infrastructure

The equipment owned and controlled by a Road Traffic Authority, for example cameras, variable road signs, roadside units, and traffic lights.

Vehicle

In the vehicle several Apps can exists; they may be integrated on different levels.

---

1 Other terms are used in some regions, e.g. Road Traffic Operator (RTO) or Infrastructure Owner Operator (IOO)

The below figure adds the communication domains (wired/cellular/short range) to the reference architecture.

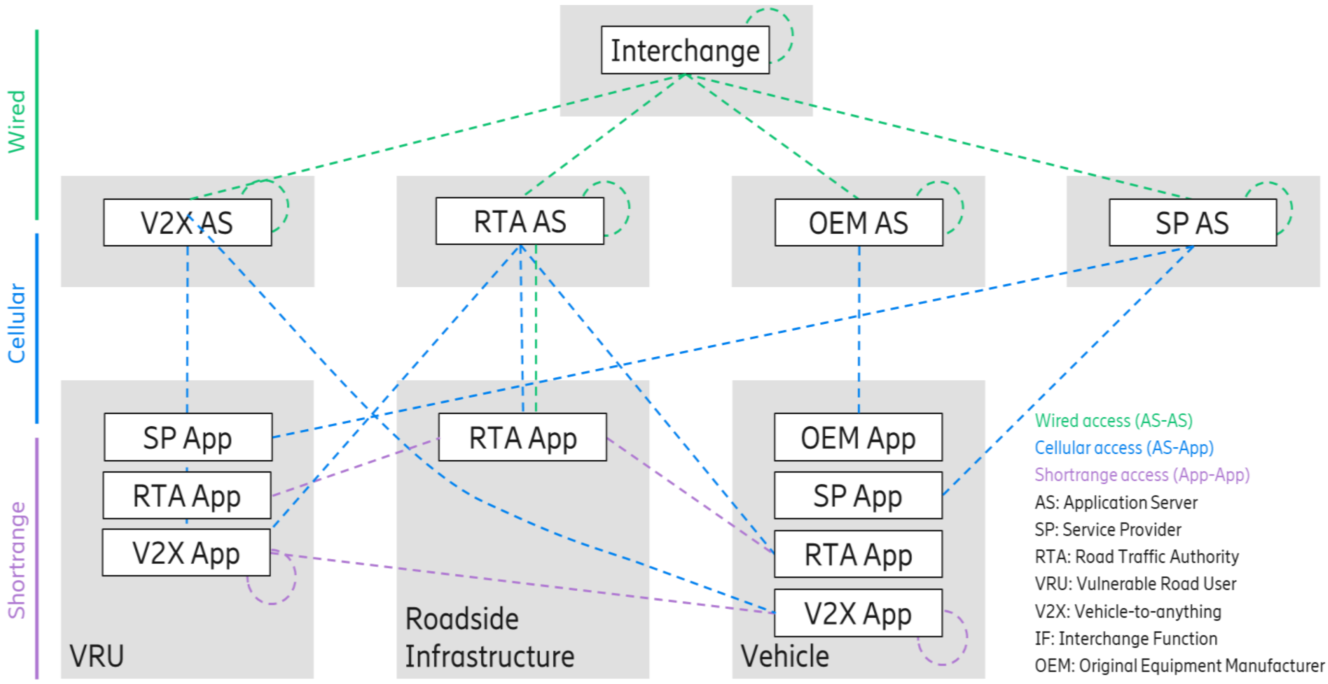

Figure 2 V2X reference architecture with different communication domains

Wired communication

This communication domain between Application servers is typically done via secured interconnections between trusted internet actors. This communication domain is also commonly known as 'backend communication'.

Cellular communication

The communication between Application Servers and their respective Apps (clients) using cellular networks of different generations.

Short-range communication

The communication between Apps (clients) using direct communication.

Communication modes

Direct communication between Apps are referred to as Vehicle-to-Infrastructure (V2I) or Vehicle-to-Vehicle (V2V)

If this communication is done via cellular networks and backend communication, the communication is referred to as Vehicle-to-Network-to-Infrastructure (V2N2I) or Vehicle-to-Network-to-Vehicle (V2N2V).

5 Wired communication

This chapter describes an applied communication architecture based on the V2X System Application Layer Reference Architecture [2] for wired (backend) communication.

5.1 Interchange

Interchanges are the entities that interconnect actors (V2X AS, RTA AS, OEM AS, SP AS) in the wired backend communication. These Interchange entities provide scalability, avoiding a full mesh of connections between the actors.

A solution to share ITS information using backend communication is specified and profiled by the C-Roads organisation [3] in the 'C-ITS IP-Based Interface Profile Version 1.7.0' (or later versions). This provides an interoperable solution between backend actors. Below, is a high-level description of the main concepts and solution.

Note, the figure below only shows two Interchange entities (sometimes also referred to as 'neutral servers') to illustrate the concept, for scalability, multiple Interchange entities can be deployed and interconnected. Also note that the Service Provider backend systems (clouds) are interchangeable with OEM backends. The terms Road Traffic Authority (RTA) and Road Operator (RO) are used only as examples in the figure; other terms are used in some regions (e.g. Road Traffic Operator (RTO) or Infrastructure Owner Operator (IOO).

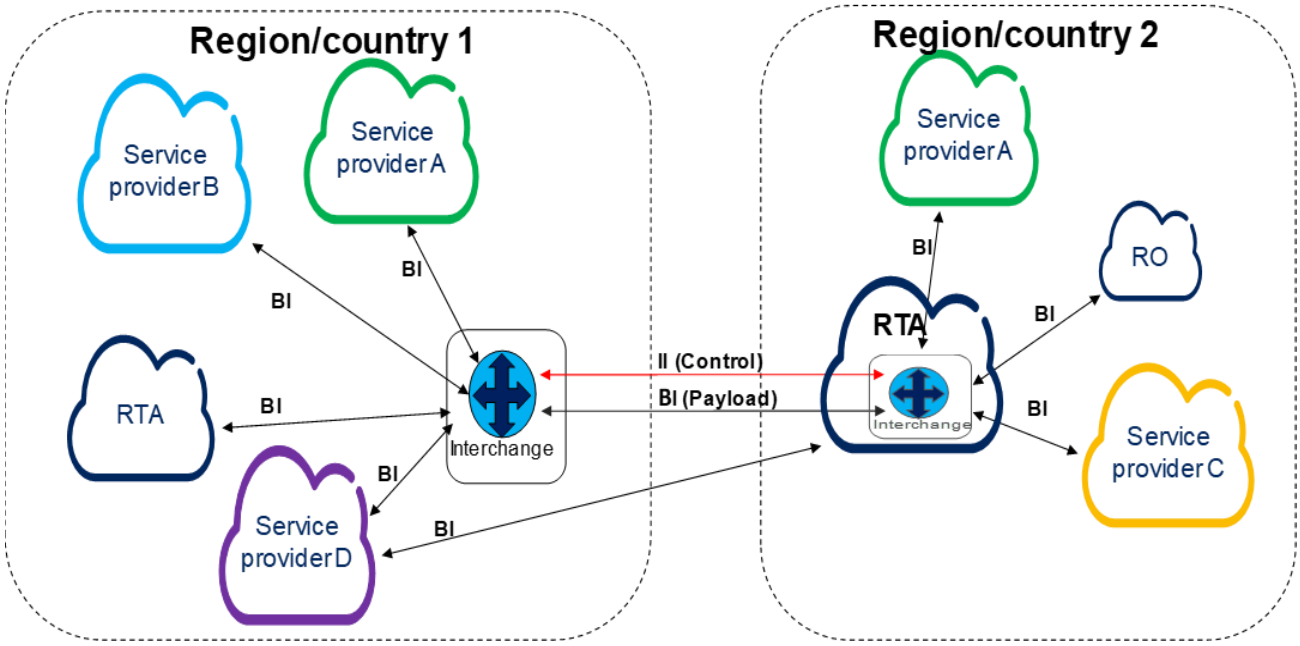

Figure 3 Simplified overview of backend architecture for information sharing

Interchange entities are Advanced Message Queuing Protocol (AMQP) brokers with additional functionality to federate information between various data sources and consumers (i.e. the above II control plane protocol can serve as a look-up entity for consumers to find the data source or it can function as an entity that fetches the information on behalf of the data consumer). The II protocol is using HTTP REST (representational state transfer) principles with encoded information using JavaScript Object Notation (JSON).

The BI protocol is using AMQP to convey information such as a Decentralized Environmental Notification Message (DENM) and In-Vehicle-Information (IVI) as a payload. Information carried in payload is identified with metadata (called AMQP application properties), and this metadata – e.g. message types, country code and related area (based on the Quadtree tile concept) – can be used to filter out relevant information.

The communication uses standard AMQP [ref 4] with a 'publish and subscribe' approach between clients and AMQP brokers, the use of AMQP has been profiled by the C-Roads platform. For instance, events and their metadata are published by producers and pushed to consumers who subscribe to information identified within the metadata. No 'tight interaction' is then required by the participating actors. This communication method can be applied between the various ASs (V2X AS, RTA AS, OEM AS, SP AS).

Payload in the AMQP messages would in many regions be based on ETSI ITS standards (e.g. [8] and [9]), and the ETSI format is used in the UC realisation. However, the AMQP layer is 'payload agnostic' and can thus convey different message formats in the payload. One format for traffic-related information that is widely used is DATEX II, as stipulated for Real-Time Traffic Information (RTTI), to interconnect regions using different message formats, specifications and translators for DATEX II ←→ ETSI are available.

If other standards are used, the AMQP payload for exchanging information between backends should be according to relevant standards for the region, i.e. if SAE is used in the region, the payload should be according to [10].

5.2 OEM AS

The OEM AS in the backend is a connected actor that uses AMQP methods to publish information towards the Interchange it is connected to (can be connected to several). The information is identified with metadata describing the type of event, location of event, etc. The OEM AS also uses AMQP methods to subscribe to information it is interested in. The OEM AS comprises a Central C-ITS station for handling AMQP payloads in order to be compliant with ETSI messages. For other regions where other standards are used, the OEM backend system shall adhere to relevant standards regarding the payload format.

5.3 SP AS

The SP AS in the backend is a connected actor that uses AMQP methods to publish information towards the Interchange it is connected to (can be connected to several). The information is identified with metadata describing the type of event, location of event, etc. The SP AS also uses AMQP methods to subscribe to information it is interested in. The SP AS comprises a Central C-ITS station for handling AMQP payloads in order to be compliant with ETSI messages. For other regions where other standards are used, the SP backend system shall adhere to relevant standards regarding the payload format.

5.4 RTA AS

The RTA AS in the backend is a connected actor that uses AMQP methods to publish information towards the Interchange it is connected to (can be connected to several). The information is identified with metadata describing the type of event, location of event, etc. The RTA AS also uses AMQP methods to subscribe to information it is interested in. The RTA AS comprises a Central C-ITS station for handling AMQP payloads in order to be compliant with ETSI messages. For other regions where other standards are used, the RTA backend system shall adhere to relevant standards regarding the payload format.

5.5 V2X AS

The V2X AS in the backend is a connected actor that uses AMQP methods to publish information towards the Interchange it is connected to (can be connected to several). The information is identified with metadata describing the type of event, location of event, etc. The V2X AS also uses AMQP methods to subscribe to information it is interested in. The V2X AS comprises a Central C-ITS station for handling AMQP payloads in order to be compliant with ETSI messages. For other regions where other standards are used, the V2X backend system shall adhere to relevant standards regarding the payload format.

6 Cellular communication

Mobile networks can provide Quality of Service/priority and in general be enhanced for more critical and important communication, e.g. per user, per flow or provide dedicated ‘network slices’.

6.1 OEM AS

The communication between a vehicle and its backend system is proprietary to the OEM, however this chapter describes different implementation models and protocols that can be used.

OEM ASs can use different cellular technology on the communication link to their OEM Apps because the interoperability is handled by the backend systems. An OEM would normally have user consent for privacy in place with its customer for telematics services. For those customers, the OEM AS can perform geolocation and geo-casting and can thus filter out relevant information for the vehicles.

Another OEM strategy to maintain privacy is for the OEM AS to know the vehicle location on a coarse level only (e.g. by country/state), thus it sends information to many vehicles and lets the vehicle algorithm sort out if the event is relevant. To maintain end-user trust, an OEM AS would also normally check the data quality before communicating with vehicles to prevent false/wrong information being conveyed.

The Message Queuing Telemetry Transport (MQTT) protocol is often used for connecting with vehicles because it is lightweight and supports increased scalability. The 5GAA C-ITS Communication System Profile Using Cellular Uu [6] could be used to transfer information.

6.2 SP AS

The communication between a SP App and its backend system is proprietary to the SP, however this chapter describes different implementation models and protocols that can be used.

SP ASs can use different cellular technology on the communication link to their SP Apps because interoperability is handled by the backend systems. A Service Provider would normally have user consent for privacy in place. For those customers, the SP AS can perform geolocation and geo-casting and can thus filter out relevant information for the SP Apps.

To maintain end-user trust, an SP AS would also normally check the data quality before communicating with vehicles to prevent false/wrong information being conveyed.

The Message Queuing Telemetry Transport (MQTT) protocol is often used for connecting with vehicles because it is lightweight and supports increased scalability. The 5GAA C-ITS Communication System Profile Using Cellular Uu [6] could be used to transfer information.

6.3 RTA AS

The communication between roadside infrastructure and its backend system is proprietary to the RTA, so this communication is not further described.

6.4 V2X AS

A V2X AS is the model when an actor provides C-ITS information to different clients (different OEMs/SPs). In this scenario the communication between V2X AS and V2X App needs to use a standardised protocol (or clients having the relevant App).

Note: In principle, there are different connectivity paths between vehicle clients and third-party service providers; directly or ‘through’ the OEM backend. Which path is used depends on multiple factors, such as security, trustworthiness, but also the services’ latency requirements.

7 Short-range communication

In this domain communication can be directly between the Apps, e.g. V2I between RTA apps, or V2V between V2X Apps using the PC5 profile for the transport layer (e.g. according to [12]), and application information according to the region, e.g. using ETSI [8,9] or SAE specifications [10].

Even though Figure 2 shows separated OEM/SP/RTA/V2X Apps in the short-range communication domain (i.e. for the vehicle), the Apps will in practice be integrated and interact. For instance, information known in the OEM App (i.e. received from the OEM AS) may be forwarded to the V2X App for transmission on short range and vice versa (if relevant). The RTA App and V2X App could also be a combined App.

Some information, such as short-range event information, is useful to share over a longer range to secure earlier notification. This communication is referred to as V2N2I or V2N2V this is reflected in the UC descriptions.

7.1 V2X App

The communication between V2X Apps is referred to as V2V.

There are two variants for V2V communication, the ETSI based variant where Cooperative Awareness Messages (CAMs) [7] are broadcasted periodically according to vehicle speed, and Decentralized Notification Messages (DENMs) [8]; the latter is thus event triggered. The other variant is based on the SAE standard and refers to as Basic Safety Messages (BSMs) [9]. For the SAE standard the same message is used for awareness and events. For both variations, vehicles are expected to be enrolled in the corresponding C-ITS PKIs.

For V2V short-range communication the messages are normally repeated by the lower protocol layers to ensure a high Packet Reception Ratio (PRR), and increase the likelihood that the message can be detected. Applications can also decide themselves the degree of message repetition depending on the use case being executed. A different variant is that the same event message is sent but with some of the information being different. An example of this would be the

Emergency Brake warning message, where the event is the same but the location would vary because the vehicle is moving while braking.

7.2 RTA App

The communication between RTA Apps are referred to as V2I.

8 UC flow prerequisites

This chapter describes prerequisites assumed in the description of use case flows.

8.1 Prerequisites for backend information sharing

For use cases using backend communication, the actors need to be interconnected as illustrated below.

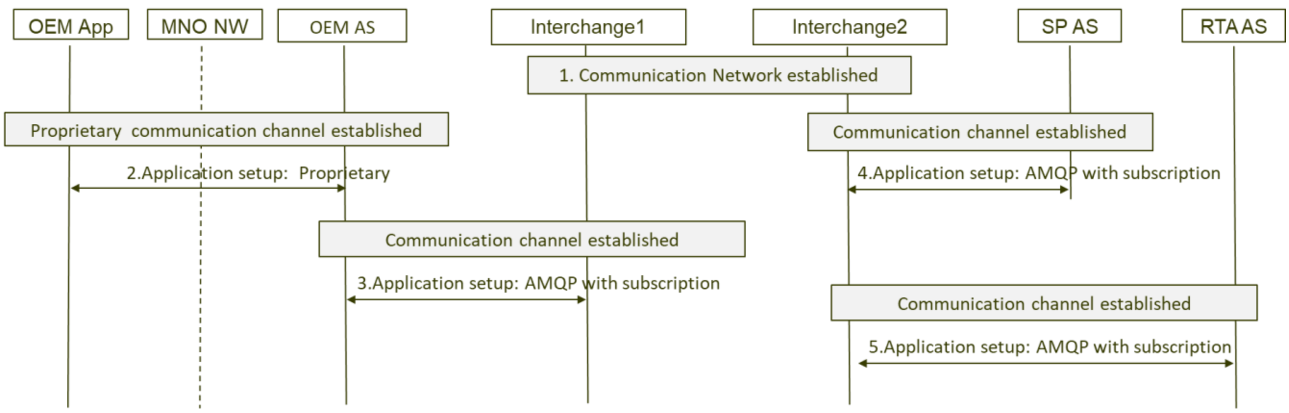

Figure 4 Setup for data sharing

1. The Interchange network is established according to C-Roads specifications [3] which are summarised in Chapter 5. The establishment includes the discovery of Interchange entities, and information exchange about capabilities, i.e. what information the actors connected to the Interchange can provide (regions/areas for which information is available), and what information is available and where. The protocol between Interchange entities allows that each entity to fetch information on behalf of the subscriber (actor) or redirect the subscriber to the data source.
2. The application communication between a client (OEM App) and its backend server (OEM AS) is proprietary to the OEM. A common approach is to base this communication link on the MQTT protocol, which provides publish/subscribe methods suitable for wireless communication.
3. The OEM AS establishes an AMQP connection to an Interchange entity and subscribes to relevant information. Subscription can be tailored on, for example, event type, location, country, e.g. an OEM could subscribe to information from countries where its vehicles are located and depending on what features are supported in the vehicles. Metadata that can be used for filtering are described in C-Roads profiles.
4. The communication between SP AS and SP App would be handled similarly to that for an OEM, i.e. proprietary. An SP AS would subscribe to similar information as an OEM AS
5. An RTA would subscribe to information related to its country or area of responsibility.

The Mobile Network Operator (MNO) relationship between OEM Apps and OEM ASs is shown in Figure 4, and indicates that mobile networks can provide Quality of Service/priority and in general be enhanced for more critical and important communication (e.g. per user, per flow or in providing dedicated ‘network slices’). This is not further reflected in the UC flows, but can be considered for more latency critical UCs.

In addition, the multiple Interchanges shown in Figure 4 are not visible in UC flows for simplicity.

8.2 Regions and standard implementation of ITS messages

As messaging variants for ITS have been standardised for the different technology implementations described above, certain defined messaging standards will be mentioned in the descriptions of the use cases presented below. The selected messages have been identified as suitable for the specific implementation of the use case. It is assumed that regions in which the Standards Developing Organisations (SDOs - ETSI, SAE and others) are located will predominantly implement their respective standards. Furthermore, certain countries and/or regions, where specific message standards come into question will be mentioned if identified. Several regions and countries are not mentioned because at the time of writing the likely messaging standard to be implemented had not been determined.

To better understand the message sequence charts and flow descriptions presented below, the name of a standardised message from one of the existing V2V variants will be used. This is clearly a visual simplification and not to be considered as a limitation of one V2V implementation variant over another. Therefore, the description of CAM equally represents BSM or DENM and vice versa. This applies, if not otherwise explicitly mentioned, to all examples outlined below.

9 UC flows

In this chapter, the UCs are mapped to the communication architecture and illustrated with sequence diagrams including main parameters conveyed.

9.1 Cross-Traffic Left-Turn Assist (LTA)

The use case Cross-Traffic Left-Turn Assist, or LTA, is described as part of the 5GAA WG1 use case descriptions Vol 1 [11]. A vehicle (host vehicle or HV) is alerted when attempting to turn left across traffic since a remote vehicle (RV) is approaching from the opposite direction in the lanes that HV needs to cross.

9.1.1 LTA using direct communication

In this scenario, the vehicle (host vehicle, HV) discovers other vehicles through direct communication.

Category	Item	Description
	Use case name	Cross-Traffic Left-Turn Assist [11]
	Relation to other use cases	n/a
	Actors and roles	HV (OEM App1): Approaches the intersection and intends to turn left RV (OEM App2): Approaches the intersection and drives straight through
	Information classification	
Standards and technology	Access layer technology/ies	Short range: PC5
	Network and transport layer technologies	Short range: GNW with BTP or WSMP

	Message standards	Short range: CAM or BSM
	Framework	n/a
Application requirements	Use case triggers	HV (driver) deciding to turn left
	Required information in the vehicles	Position, velocity, heading, detection of oncoming vehicles
Network layer requirements	Required coverage	n/a
	Required availability	Provide all equipped vehicles approaching an intersection with information about oncoming vehicles, in a timely fashion according to the SLRs as defined in the use case description

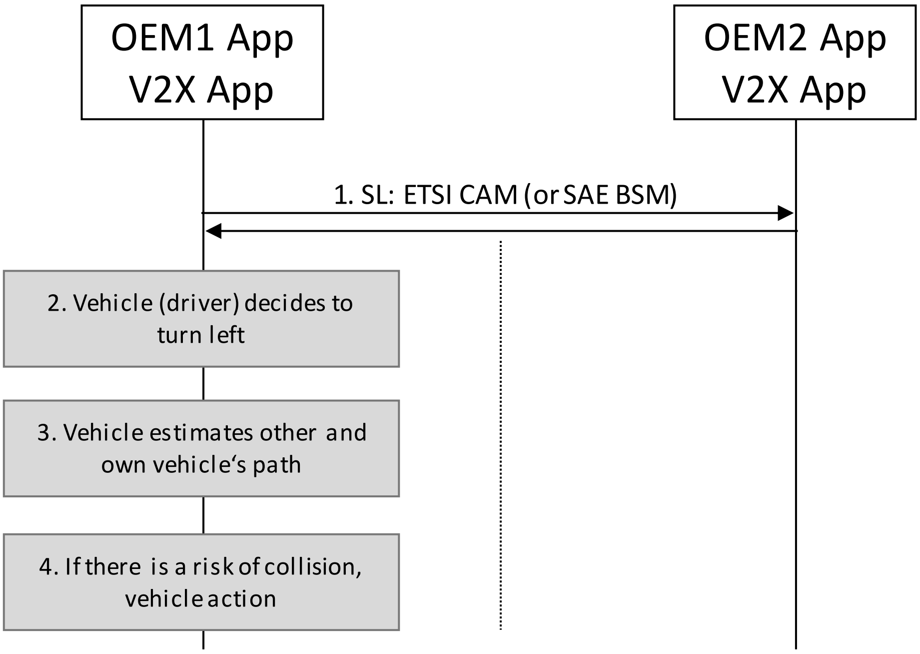

Figure 5 Left Turn Assist

1. Vehicles periodically broadcast CAMs (or BSMs) informing surrounding vehicles amongst others regarding their position, heading, and velocity.
2. HV (OEM1 App V2X App) (driver) decides to turn left (e.g. by turning on the left turn indicator)
3. HV estimates RV's (OEM2 App V2X App) trajectory based on CAMs (or BSMs) received from RV. HV also predicts its own path.
4. If based on this estimation and prediction there is a risk of collision, depending on the OEM implementation / the vehicle type, OEM App informs / warns the HV driver and/or stops HV.

The following table provides a matching of the above-described solution to SLRs defined as part of the user stories in [11]. SLRs highlighted in green are expected to be fulfilled according to comments giving in the comment column.

User story	Range [m]	Information requested/ generated	Service level latency [ms]	Service level reliability	Vehicle density [vehicle/km^2]	Comments
#1	300	300B/message	100	90%	1500	Expected to fulfil SLRs using C-V2X direct with standardised message set
#2	300	1000 B/message	10	99.9%	1500	User story needs a separate implementation description

9.1.2 LTA coordinated by road authority/road operator

In this scenario the Left-Turn Assist is coordinated by RTA AS based on various inputs. **It is assumed** that the roadside infrastructure at the intersection has real-time traffic data collection and reporting capabilities and that the backend system/RTA AS is already equipped with algorithms which can achieve functions such as target detection, positioning, and tracking. In addition, we also assume that the respective RTA and OEM Apps for this scenario are both installed on the HV.

The below table summarises the main properties and requirements for this UC realisation:

Category	Item	Description
	Use case name	Cross-Traffic Left-Turn Assist [11]
	Relation to other use cases	Intersection Movement Assist (IMA) use case could be triggered at the same time when the vehicle is turning left at the intersection During the Left-Turn Assist, if there is a risk of collision with the oncoming vehicles, vehicles might have to brake strongly and trigger EEBL use cases
	Actors and roles	RTA App: Collect and reports perceptual data at the intersection to RTA AS RTA AS: Determines left-turn risk and informs Interchange entities: connects RTA AS, OEM AS, and SP AS OEM AS: Sends LTA information to HV HV(RTA App): Sends driving information to RTA AS and RTA App HV (OEM App): Receives LTA information from OEM AS
	Information classification	LTA is provided explicitly to HV
Standards and technology	Access layer technology/ies	Wired: Ethernet Cellular: 3GPP LTE Uu or NR Uu Short range: PC5
	Network and transport layer technologies	Wired: UDP/TCP/IPv4/v6 Cellular: UDP/TCP/IPv4/v6

		Short range: GNW with BTP, or WSMP
	Message standards	Wired: AMQP, encapsulating any combination of: DATEX II, and/or proprietary and/or DENM, BSM Cellular: Proprietary and/or CAM, DENM, BSM Short range: CAM and/or DENM, BSM
	Framework	V2XSRA, through OEM AS, SP AS, RTA AS, and Interchange; framework needs to include capabilities to achieve functions such as target detection, positioning and tracking, and to alert all equipped vehicles turning left at the intersection about traffic approaching from the opposite, left, or right direction in a timely fashion according to the SLRs as defined in the use case description
Application requirements	Use case triggers	Proprietary (RTA App on vehicles)
	Required information in the vehicles	Own vehicle kinematics
Network layer requirements	Required coverage	Cellular network coverage of road network
	Required Availability	Alert all equipped vehicles turning left at the intersection of the traffic approaching from the opposite, left, or right direction in a timely fashion according to the SLRs as defined in the use case description

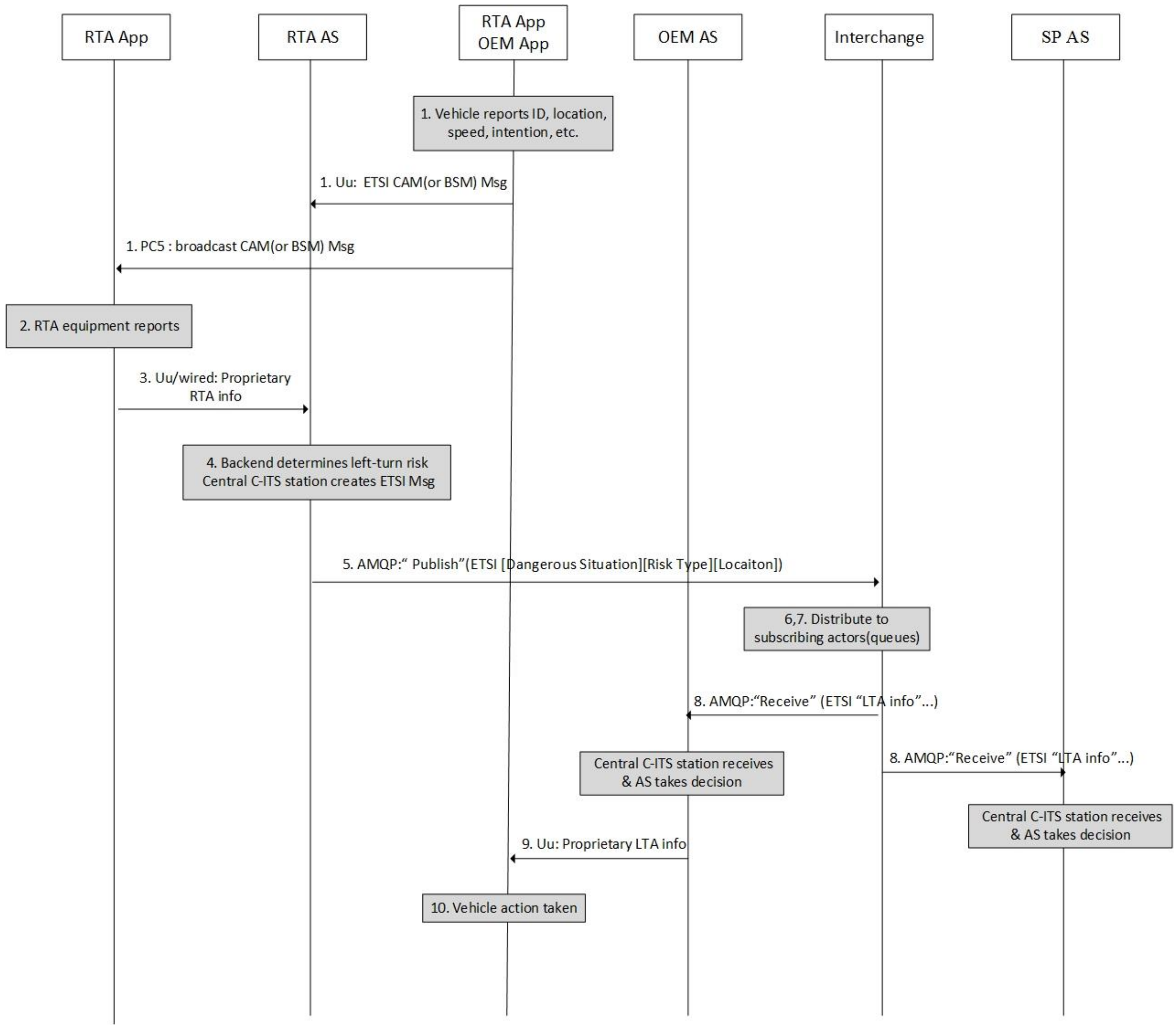

Figure 6 Left-turn assist performed by RTA

1. By creating CAMs (or BSMs), vehicles report their ID, location, speed, driving intention information (e.g. by the vehicles turning indicators), etc. to the RTA AS and/or RTA App on the roadside infrastructure when arriving at the intersection, through Uu and/or PC5 interfaces respectively.
2. The roadside infrastructure (e.g. camera, radar, etc.) is arranged to collect perceptual data of vehicles passing through the intersection.
3. The roadside infrastructure reports, for example, camera videos, radar data (this communication could take place on a wired connection as well).
4. After analysing reports, the backend determines that there is a risk for vehicles turning left. The backend that contains a Central C-ITS station, as defined by ETSI, creates a DENM with the essential parameters, such as a *cause code* indicating 'dangerous situation', e.g. 'collision risk', a *sub-cause code* indicating detailed information about a 'dangerous situation', e.g. "acceleration or direction change of oncoming vehicles', reference position, etc.
5. The DENM is published on the Interchange with the AMQP payload containing the message and the properties fields contain metadata for filtering, e.g. location of event (which geographic tile) and type of event.
6. The Interchange entity looks at the AMQP properties fields, and distributes to respective actors subscribing to the information.
7. The message is added to the relevant queues; in this example the OEM AS and the SP AS have subscribed to the information (e.g. DENMs) in a specific area (geographic tile).

8. The OEM AS and SP AS receives the DENM and analyses it. Confident in the data quality, the OEM AS and SP AS (not shown in sequence) then distribute the LTA information to relevant (potentially affected) clients or to other actors that the SP serves, e.g. OEMs. Note: an OEM AS would perform similar actions as the SP AS.
9. The LTA information is sent to the relevant vehicles on the cellular connection (Uu). The format used to convey this information could be according to OEM-specific protocols, or the ETSI format could be used; the 5GAA Uu profile could also potentially be used to transfer the ETSI message.
10. Depending on functionality, the OEM App in the vehicle can, for example, warn of collision risk by sounding an alarm, and indicate on its dashboard the current position of dangerous vehicles. If the OEM App client interacts with autonomous driving onboard systems, it can notify the system to brake or reduce speed to achieve a smooth and safe left turn.

The following table provides a matching of the above-described solution to SLRs defined as part of the user stories in [11]. SLRs highlighted in green are expected to be fulfilled according to comments giving in the comment column.

User story	Range [m]	Information requested/ generated	Service level latency [ms]	Service level reliability	Vehicle density [vehicle/km^2]	Comments
#1	300	300B/message	100	90%	1500	Expected to fulfil SLRs using C-V2X Uu and PC5 with standardised message set. Please note that the latency here means the one-way application layer latency for radio communication (e.g. HV to RTA APP/AS, OEM AS to HV)
#2	300	1000 B/message	10	99.9%	1500	User story needs a separate implementation description

9.2 Emergency Brake Warning

The use case emergency brake warning is described as part of the 5GAA WG1 use case descriptions Vol 1 [11]. A (host) vehicle is alerted when another vehicle (a remote vehicle) is braking.

9.2.1 Vehicle is braking hard

In this scenario, **it is assumed** that the host vehicle is braking hard, as determined by the conditions in C2C-CC triggering conditions [6]), for example.

The below table summarises the main properties and requirements for this UC realisation:

Category	Item	Description
	Use case name	Emergency Brake Warning (Electronic Emergency Brake Light - EEBL) [11]
	Relation to other use cases	EEBL might be the cause for TJW EEBL might transition into stationary vehicle warning

	Actors and roles	HV: Receives EEBL from RV (if in line-of-sight, if applicable can confirm with onboard sensors) RV(s): Decelerates with more than xx m/s^2 (see trigger conditions) and broadcasts EEBL message Other actors involved: Interchange, SP AS, OEM AS, and RTA AS
	Information Classification	EEBL is provided explicitly to HV
Standards and technology	Access layer technology/ies	Wired: Ethernet Cellular: 3GPP LTE Uu or NR Uu Short range: PC5
	Network and transport layer technologies	Wired: UDP/TCP/IPv4/v6 Cellular: UDP/TCP/IPv4/v6 Short range: GNW&BTO or WSMP
	Message standards	Wired: AMQP, encapsulating any combination of: DATEX II, proprietary message(s), DENM, BSM. Cellular: Proprietary, and/or DENM or BSM Short range: DENM or BSM
	Framework	V2XSRA, through OEM AS, SP AS, RTA AS, and Interchange; framework needs to include capability to provide all equipped vehicles approaching the traffic jam with the warning in a timely fashion according to the SLRs as defined in the use case description
Application requirements	Use case triggers	See e.g. [6]
	Required information in the vehicles	Velocity, detection of vehicles ahead/behind – or surrounding
Network layer requirements	Required coverage	Cellular network coverage of road network
	Required Availability	Provide all equipped vehicles approaching the braking vehicle with EEBL in a timely fashion according to the SLRs defined in the use case description

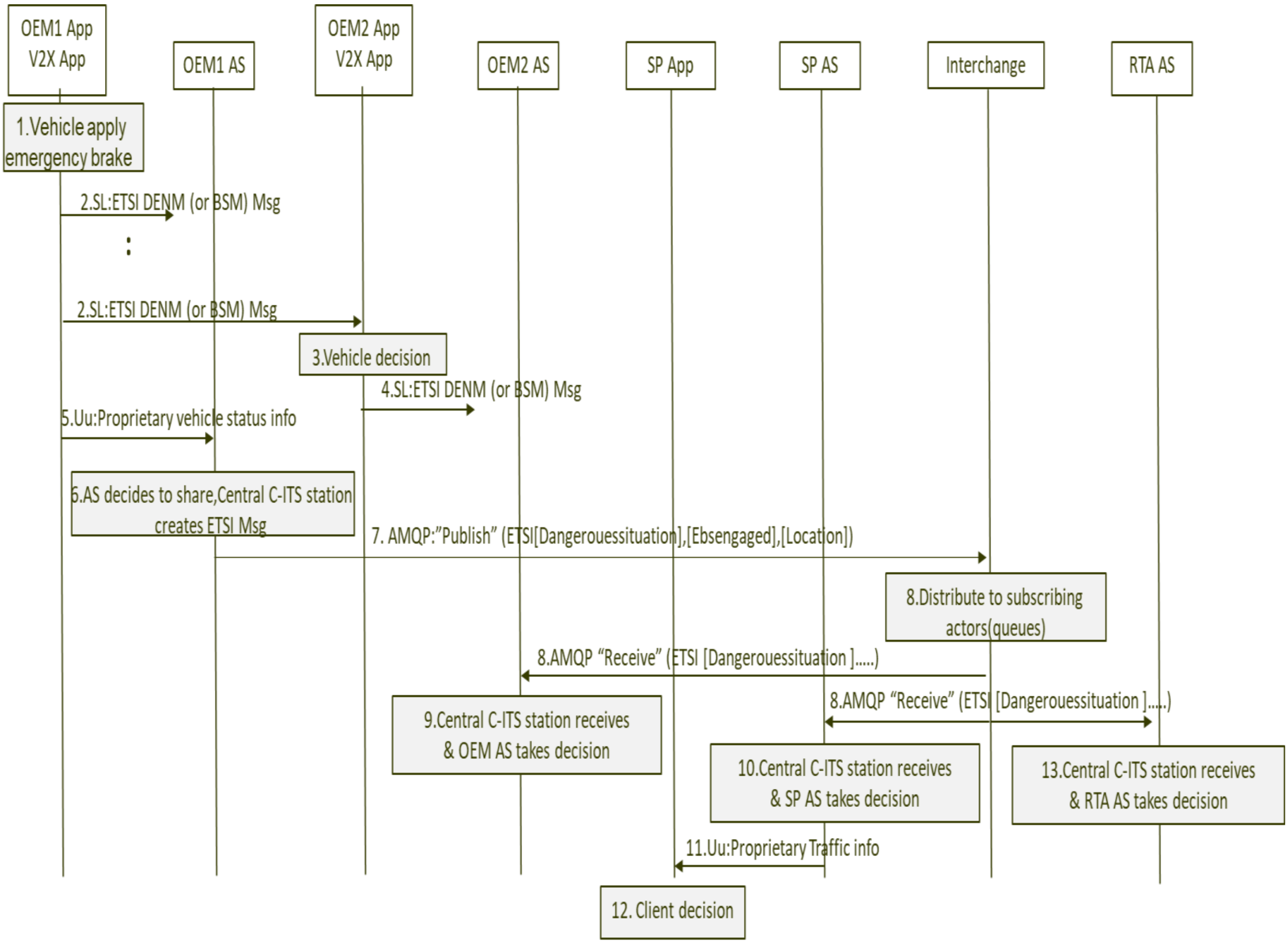

Figure 7 Emergency brake information shared

1. Vehicle 1 (HV) is braking hard.
2. The HV creates a DENM (or sets the corresponding flag in BSMs) indicating the emergency brake system is engaged and broadcasts the information short range to surrounding vehicles. The message is repeated in accordance with the triggering conditions to increase the probability. This is further elaborated in chapter 7. In the EEBL case, messages are also repeated as long as an event is present, in this case the hard braking event.
3. A nearby vehicle receives the DENM(s) and determines appropriate action(s), if available in combination with additional information.
4. If vehicle 2 is also braking hard, it creates and broadcasts the corresponding DENM.
5. The hard-braking vehicle 1 informs its backend system about the event using the cellular link (Uu). This would in most cases be done using the OEM proprietary connection in place for other telematics services. The format used to convey the traffic jam information could be according to an OEM-specific protocol, or the ETSI format could be used. The 5GAA Uu profile [Ref 6] could also potentially be used to transfer the ETSI message.
6. The algorithm in the OEM backend decides that this event should be shared; the backend contains a Central C-ITS station, as defined by ETSI, which creates a DENM with the essential parameters, such as a *cause code* indicating 'dangerous situation', a *subcause code* indicating the type of 'dangerous situation', e.g. 'emergency brake engaged', reference position, etc. The Central C-ITS station avoids communicating any personal data and thus ensures the message is anonymised. The OEM backend may also inform its own vehicles potentially affected by the traffic jam. The backend could also ensure the data quality before sharing any information (e.g. based on input from multiple sources).
7. The DENM is published on the Interchange using the AMQP payload containing the DENM, the AMQP properties fields contain the metadata for filtering, e.g. location of event (which geographic tile) and type of event.
8. The Interchange entity looks at the AMQP properties fields and distributes information to subscribers (actors) as indicated by the AMQP fields, excluding the publishing actor.
9. The OEM2 AS subscribes to this type of event in the area and receives relevant information about the event. Since only one event (or a limited number) is received, the OEM2 AS algorithm can wait for further events before informing its vehicles, i.e. to ensure data quality and greater confidence in the communication.

10. SP AS also receives the DENM and analyses it. In this example, the SP AS uses a different strategy to OEM2 AS by having the SP App ensure the data quality, i.e. the algorithm in the App decides when and what action to take. The SP clients could be an OEM AS if the SP provides the service for an OEM.
11. The information about the hard-braking event is sent to the client on the cellular connection (Uu) and if the client resides in the backend, then wired communication is used. The format used to convey the information could be according to SP-specific protocol, or the ETSI format could be used. The 5GAA Uu profile [6] could also potentially be used to transfer the ETSI message.
12. Depending on functionality and location, the client can, for example, indicate the hard-braking event on the vehicle dashboard or on a route map. The algorithms could also wait for more events to increase confidence before taking action.
13. If the RTA AS's confidence in the event is boosted by more events or verified by cameras it may decide to share the information on other available channels, e.g. changing variable road signs. The RTA AS may also use the information for statistical analysis, e.g. identify locations that often have hard-braking situations for road planning.

The following table provides a matching of the above-described solution to SLRs defined as part of the user stories in [11]. SLRs highlighted in green are expected to be fulfilled according to comments giving in the comment column.

User story	Range [m]	Information requested/ generated	Service level latency [ms]	Service level reliability	Vehicle density [vehicle/km^2]	Comments
#1	360	200-400B/message	120	99.99%	10,000	Expected to fulfil SLRs using C-V2X direct with standardised message set The additional dissemination of related information through the backend (steps 5-13 in Figure 8) can enhance the overall traffic safety
#2	290	200-400B/message	120	99.99%	10,000	Expected to fulfil SLRs using C-V2X direct with standardized message set. The additional dissemination of related information through the backend (steps 5-13 in Figure 6) can enhance the overall traffic safety

9.3 Traffic Jam and Route Information

The traffic jam warning and route information use case is described as part of the 5GAA WG1 use case descriptions Vol 1 [11]. A vehicle (host vehicle) is warned of an approaching traffic jam on route or notified about a traffic jam on the navigation route.

9.3.1 Traffic jam determined by vehicle

In this scenario, the traffic jam (TJ) is determined by a vehicle based on various input. **It is assumed** that the traffic jam is already present for this UC description, i.e. to determine that a TJ is about to happen is more complex and requires additional algorithms.

The below table summarises the main properties and requirements for this UC realisation:

Category	Item	Description
	Use case name	Traffic Jam Warning [11]
	Relation to other use cases	Origin of the traffic jam might be an obstacle on the road (‘obstacle warning use case’), roadworks (‘roadworks warning use case’), or a stationary vehicle (‘stationary vehicle warning use case’) Vehicles approaching the end of the traffic jam might have to brake strongly and trigger EEBL use cases
	Actors and roles	RV (OEM App): Determines TJ and provides information about TJ to OEM AS OEM AS: Receives TJW from RV, forwards to HV and Interchange HV: Receives TJW from the OEM AS Other actors involved: Interchange, SP AS, and RTA AS
	Information classification	RV (OEM App) is explicitly detecting TJ TJW is provided explicitly to HV
Standards and technology	Access layer technology/ies	Wired: Ethernet Cellular: 3GPP LTE Uu or NR Uu Short range: PC5
	Network and Transport layer technologies	Wired: UDP/TCP/IPv4/v6 Cellular: UDP/TCP/IPv4/v6 Short range: GNW with BTP or WSMP
	Message standards	Wired: AMQP, encapsulating any combination of: DATEX II, proprietary message(s), DENM Cellular: Proprietary and/or DENM Short range: DENM
	Framework	V2XSRA, through OEM AS, SP AS, RTA AS, and Interchange. Framework needs to include capability to provide all equipped vehicles approaching the traffic jam with the warning in time according to the SLRs as defined in the use case description.
Application requirements	Use case triggers	See e.g. [5]
	Required information in the vehicles	Velocity, detection of vehicles ahead/behind – or surrounding

Network layer requirements	Required coverage	Cellular network coverage of road network
	Required Availability	Provide all equipped vehicles approaching the traffic jam with the warning in a timely fashion according to the SLRs as defined in the use case description

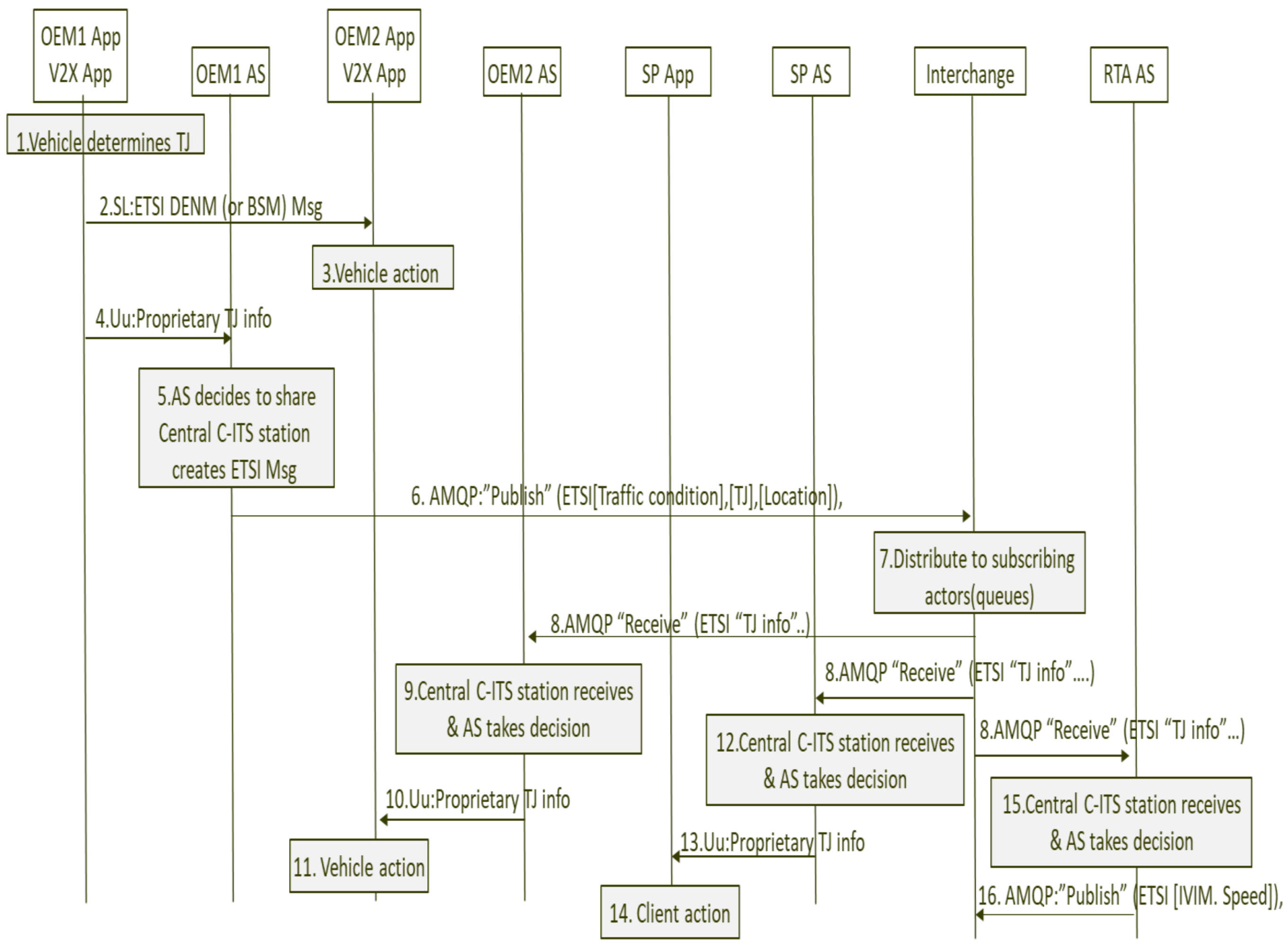

Figure 8 Sharing of traffic jam detected by vehicle

1. Vehicle algorithms decide to communicate a traffic jam, e.g. based on radar detection, or slow speeds detected on a road, or based on the methods described in C2C-CC (Triggering Conditions and Data Quality Traffic Jam) [ref 5], or based on a combination of inputs.
2. The vehicle creates a Traffic Jam Warning message according to DENM format and broadcasts the information to surrounding vehicles with short-range capabilities.
   Note 1: Only one instance of the broadcasted message shown, in many cases the message is repeated to increase the probability that message is detected and to achieve a high Packet Reception Ratio (PRR). This is further elaborated in Chapter 7. Note 2: There is no explicit traffic jam notification through BSM, however vehicles can detect TJs implicitly when several vehicles are registering low velocities in their BSMs (similar to CAMs).
3. A receiving vehicle's algorithm decides what actions to take. This is normally based on sensor fusion; in the event that it cannot verify the event with its own sensors, its algorithms may decide not to share the event further. Algorithms may still inform the driver about a potential traffic jam.
4. The vehicle informs its backend system about the detected traffic jam using the cellular link (Uu). This would in most cases be done using the OEM proprietary connection in place for other telematics services. The format used to convey the traffic jam information could be according to an OEM-specific protocol, or the ETSI format could be used. The 5GAA Uu profile [Ref 6] could also potentially be used to transfer the ETSI message.

5. The OEM backend contains a Central C-ITS station, as defined by ETSI, which creates a DENM with the essential parameters, such as a *cause code* indicating ‘traffic condition”, a *subcause code* indicating the type of ‘traffic jam’, reference position etc. The Central C-ITS station avoids communicating any personal data and thus ensures the message is anonymised. The OEM backend may also inform its own vehicles potentially affected by the traffic jam. The backend could also ensure the data quality before sharing any information (e.g. based on input from multiple sources).
6. The DENM is published on the Interchange using the AMQP payload containing the DENM, the AMQP properties fields contain the metadata for filtering, e.g. location of event (which geographic tile) and type of event.
7. The Interchange entity looks at the AMQP properties fields and distributes information to subscribers (actors) as indicated by the AMQP fields, excluding the publishing actor.
8. The message is put in the relevant queues, in this example the OEM2 AS, SP AS and the RTA AS have subscribed to the information, for example to DENMs in a specific area (geographic tile).
9. The OEM2 AS receives the DENM message and analyses it, potentially waiting for more traffic jam warnings to ensure it is a true event. When confident in the data quality, the OEM2 AS distributes the traffic jam information to relevant (potentially affected) vehicles.
10. Information is conveyed to the vehicle(s) via its cellular connection (Uu).
11. Depending on functionality, the OAM App can for example indicate the traffic jam on a vehicle dashboard, update a map and propose a new route, etc. If the MAPOEM App interacts with self-driving onboard systems, it can for example notify them to reduce speed safely and comfortably.
12. The SP AS receives the DENM message and analyses it, potentially waiting for more traffic jam warnings to ensure it is a true event. When confident in the data quality, the SP AS distributes the traffic jam information to relevant (potentially affected) clients or to other actors that the SP serves, e.g. OEMs.
13. The traffic jam information is sent to client(s) via the cellular connection (Uu). The format used to convey the traffic jam information could be according to SP-specific protocol, or the ETSI format could be used. The 5GAA Uu profile [Ref 6] could also potentially be used to transfer the ETSI message.
14. Depending on functionality, the SP client can indicate the traffic jam on a vehicle dashboard, update a map, propose new routes, etc. If the SP client interacts with self-driving onboard systems, it can for example notify the system to reduce speed safely and comfortably.
15. The RTA AS may share the information on other available channels, e.g. changing variable road signs. The RTA AS may also use the traffic jam information for statistical analysis.
16. In this example, the RTA decides to impose a temporary speed limit and thus publish an Infrastructure-to-Vehicle-Information-Message (IVIM) to the Interchange to indicate the temporary speed restriction for the road stretch. (Distribution to actors subscribing to this type of information is not shown in Figure 7, but would follow the same principles as for the DENM.)

The following table provides a matching of the above-described solution to SLRs defined as part of the user stories in [11]. SLRs highlighted in green are expected to be fulfilled according to comments giving in the comment column.

User story	Range [m]	Information requested/ generated	Service level latency [ms]	Service level reliability	Vehicle density [vehicle/km^2]	Comments
#1	1000	200-400B/message	2000	50%	10,000	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members
#2	1000	200-400B/message	2000	50%	500	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members
#3	1000	200-400B/message	2000	50%	5000	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members

#4	100,000	200-400B/message	Minutes	50%	10,000	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.
#5	200,000	200-400B/message	Minutes	50%	500	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.
#6	300,000	200-400B/message	Minutes	50%	5000	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.

9.3.2 Traffic jam determined by OEM/SP AS

In this scenario the traffic jam is determined by OEM AS based on vehicle reports. Note: A similar determination could be done by a SP AS. **It is assumed** that the traffic jam is already present for this UC description, i.e. to determine that a traffic jam is about to happen is more complex and requires additional algorithms.

The below table summarises the main properties and requirements for this UC realisation:

Category	Item	Description
	Use case name	Traffic Jam Warning [11]
	Relation to other use cases	Origin of the traffic jam might be an obstacle on the road (‘obstacle warning use case’), roadwork (‘roadworks warning use case’), or a stationary vehicle (‘stationary vehicle warning use case’) Vehicles approaching the end of the traffic jam might have to brake strongly and trigger EEBL use cases
	Actors and roles	RVs (OEM App): Reports kinematic data to OEM AS OEM AS: Receives kinematic data from fleet and determines traffic jams; informs HV and Interchange HV: Receives TJW from the OEM AS Other actors involved: Interchange, SP AS, and RTA AS
	Information classification	RV(s) do not provide explicit information about TJ TJW is provided explicitly to HV
Standards and technology	Access layer technology/ies	Wired: Ethernet Cellular: 3GPP LTE Uu or NR Uu
	Network and Transport layer technologies	Wired: UDP/TCP/IPv4/v6 Cellular: UDP/TCP/IPv4/v6
	Message standards	Wired: AMQP, encapsulating any combination of: DATEX II, proprietary message(s), DENM (EU). Cellular: Proprietary and/or DENM

	Framework	V2XSRA, through OEM AS, SP AS, RTA AS, and Interchange; framework needs to include capability to provide all equipped vehicles approaching the traffic jam with the warning in a timely fashion according to the SLRs defined in the use case description
Application requirements	Use case triggers	Proprietary (OEM AS/SP AS)
	Required information in the vehicles	Own vehicle kinematics
Network layer requirements	Required coverage	Cellular network coverage of road network
	Required Availability	Provide all equipped vehicles approaching the traffic jam with the warning in a timely fashion according to the SLRs defined in the use case description

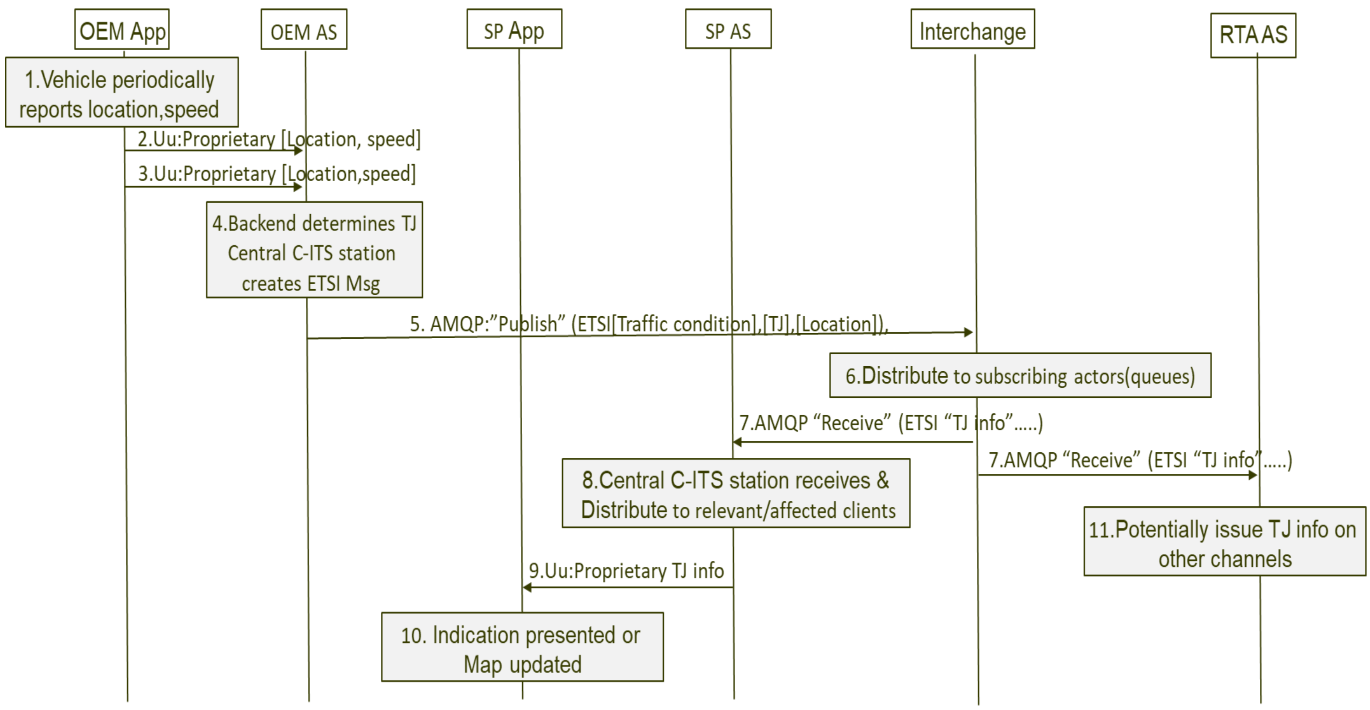

Figure 9 Sharing of traffic jam info detected by OEM AS

1. The vehicle is instructed to periodically report its location, speed etc. The reporting interval can be adjusted from the backend, e.g. depending on scenario.
2. The vehicle periodically reports information to the backend, e.g. every minute.
3. The vehicle periodically reports information to the backend, e.g. every minute.
4. The backend determines that there is a traffic jam based on vehicle reports. The backend contains a Central C-ITS station, as defined by ETSI, which creates a DENM with the essential parameters, such as a *cause code* indicating 'traffic condition', a *subcause code* indicating the type of 'traffic jam', reference position etc. The

Central C-ITS station avoids generating personal data to ensure that the message is anonymised. The OEM backend may also inform its own vehicles potentially affected by the traffic jam, and ensures the data quality based on input from multiple sources before sharing in order to boost confidence in the communication.

5. The DENM is published on the Interchange using the AMQP payload containing the ETSI message. The AMQP properties fields contain metadata for filtering, e.g. location of event (which geographic tile) and type of event.
6. The Interchange entity looks at the AMQP properties fields, and distributes information to subscribers (actors) indicated by these fields.
7. The message is added to the relevant queues; in this example, the SP AS and the RTA AS have subscribed to the information, i.e. DENMs in a specific area (geographic tile).
8. The SP AS receives the DENM message and analyses it, potentially waiting for more traffic jam warnings to ensure it is a true event. Once confident in the quality of the data, the SP AS distributes the traffic jam information to relevant (potentially affected) clients or to other actors that the SP serves, e.g. OEMs. Note: An OEM AS would perform similar actions to the SP AS.
9. The traffic jam information is sent to the client via the cellular connection (Uu). The format used to convey the traffic jam information could be according to SP-specific protocol, or the ETSI format could be used. The 5GAA Uu profile could also potentially be used to transfer the ETSI message.
10. Depending on functionality, the SP client can for example indicate the traffic jam on vehicle dashboards, update maps and propose new routes, etc. If the SP client interacts with self-driving onboard systems, it can for example notify them to reduce speed safely and comfortably.
11. The RTA AS may share the information on other available channels, e.g. changing variable road signs. The RTA AS may also use the traffic jam information for statistical analysis.

The following table provides a matching of the above-described solution to SLRs defined as part of the user stories in [11]. SLRs highlighted in green are expected to be fulfilled according to comments giving in the comment column.

User story	Range [m]	Information requested/ generated	Service level latency [ms]	Service level reliability	Vehicle density [vehicle/km^2]	Comments
#1	1000	200-400B/message	2000	50%	10,000	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members
#2	1000	200-400B/message	2000	50%	500	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members
#3	1000	200-400B/message	2000	50%	5000	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members
#4	100,000	200-400B/message	Minutes	50%	10,000	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.
#5	200,000	200-400B/message	Minutes	50%	500	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.

#6	300,000	200-400B/message	Minutes	50%	5000	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.

9.3.3 Traffic jam determined by road authority/road operator

In this scenario, the traffic jam is determined by RTA AS based on various input. **It is assumed** that the traffic jam is already present for this UC description, i.e. to determine that a traffic jam is about to happen is more complex and requires additional algorithms.

The below table summarises the main properties and requirements for this UC realisation:

Category	Item	Description
	Use case name	Traffic Jam Warning [11]
	Relation to other use cases	Origin of the traffic jam might be an obstacle on the road ('obstacle warning use case'), roadwork ('roadworks warning use case'), or a stationary vehicle ('stationary vehicle warning use case') Vehicles approaching the end of the traffic jam might have to brake strongly and trigger EEBL use cases
	Actors and roles	RTA App: Reports traffic situation to RTA AS RTA AS: Determines traffic jam and informs Interchange OEM AS: Sends TJW to HV HV (OEM App): Receives TJW from OEM AS Other actors involved: Interchange and SP AS
	Information Classification	TJW is provided explicitly to HV
Standards and technology	Access layer technology/ies	Wired: Ethernet Cellular: 3GPP LTE Uu or NR Uu
	Network and transport layer technologies	Wired: UDP/TCP/IPv4/v6 Cellular: UDP/TCP/IPv4/v6
	Message standards	Wired: AMQP, encapsulating any combination of: DATEX II, proprietary message(s), DENM (EU). Cellular: Proprietary and/or DENM
	Framework	V2XSRA, through OEM AS, SP AS, RTA AS, and Interchange; framework needs to include capability to provide all equipped vehicles approaching the traffic jam with the warning in a timely fashion according to the SLRs defined in the use case description

Application requirements	Use case triggers	Proprietary (RTA)
	Required information in the vehicles	n/a
Network layer requirements	Required coverage	Cellular network coverage of road network
	Required availability	Provide all equipped vehicles approaching the traffic jam with the warning in a timely fashion according to the SLRs defined in the use case description

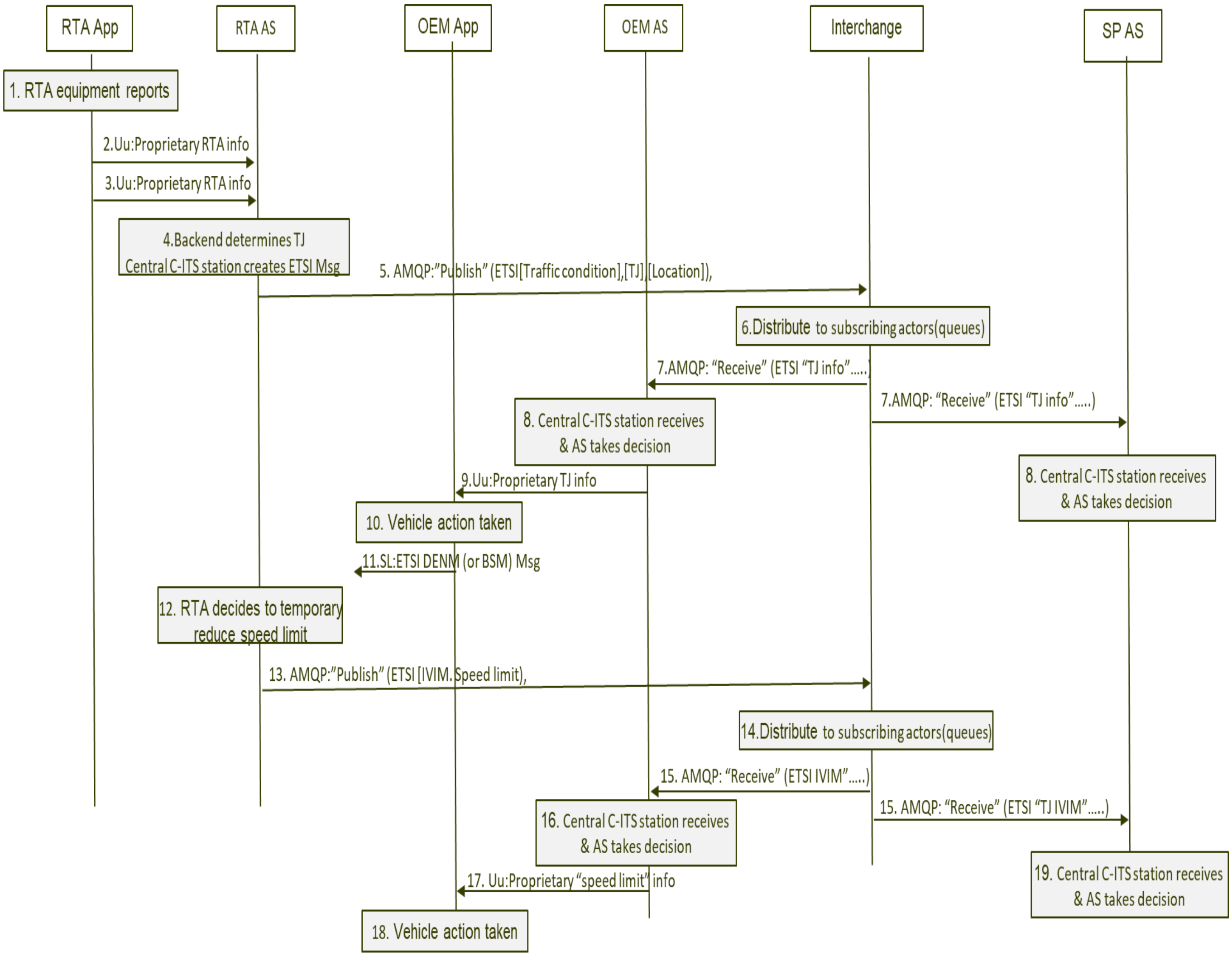

Figure 10 Sharing of traffic jam detected by RTA

1. The roadside infrastructure (e.g. cameras, inductive loops etc.) is arranged to report traffic information.
2. The roadside infrastructure reports, for example, camera images or detected vehicle speed (this communication could take place on a wired connection as well).
3. The roadside infrastructure reports, for example, camera images or detected vehicle speed (this communication could take place on a wired connection as well).
4. The backend determines that there is a traffic jam based on an analysis of reports. It contains a Central C-ITS station, as defined by ETSI, which creates an DENM with the essential parameters, such as a *cause code* indicating 'traffic condition', a *subcause code* indicating the type of 'traffic jam', reference position, etc.

5. The DENM is published on the Interchange using the AMQP payload containing the ETSI message. The AMQP properties fields contain metadata for filtering, e.g. location of event (which geographic tile) and type of event.
6. The Interchange entity looks at the AMQP properties fields and distributes information to subscribers (actors) indicated by these fields.
7. The message is added to the relevant queues; in this example the OEM AS and the RTA AS have subscribed to the information (e.g. DENMs in a specific area or geographic tile).
8. The OEM AS and SP AS receive the DENM and analyse it, potentially waiting for more traffic jam warnings to ensure it is a true event. Once confident in the data quality, the OEM AS and SP AS (not shown in sequence) distribute the traffic jam information to relevant (potentially affected) clients or to other actors that the SP serves, e.g. OEMs. Note: An OEM AS would perform similar actions to the SP AS.
9. The traffic jam information is sent to the relevant vehicles on the cellular connection (Uu). The format used to convey the traffic jam information could be according to an OEM-specific protocol, or the ETSI format could be used. The 5GAA Uu profile could also potentially be used to transfer the ETSI message.
10. Depending on functionality, the OEM App in the vehicle can, for example, indicate the traffic jam on its dashboard, update maps and propose new routes, etc. If the OEM App client interacts with self-driving onboard systems, it can for example notify them to reduce speed safely and comfortably.
11. If the vehicle is equipped with short-range capabilities and enrolled in the C-ITS PKI, and if relevant for ascertaining the location, it creates a DENM traffic jam warning and broadcasts the information to surrounding vehicles.
12. The RTA AS may share the information on other available channels, e.g. changing variable road signs. The RTA AS may also use the traffic jam information for statistical analysis, In this example, the RTA decides to impose a temporary speed limit and thus publish an Infrastructure-to-Vehicle-Information Message (IVIM) to the Interchange to indicate the temporary speed limit for the road stretch.
13. The IVIM is published on the Interchange.
14. The Interchange distributes the IVIM to subscribing actors.
15. The IVIM is received by the subscribing OEM AS.
16. The OEM AS has vehicles affected by the speed limit information and decides to inform these vehicles.
17. The speed limit information is sent to the relevant vehicles on the cellular connection (Uu). The format used to convey the information could be according to an OEM-specific protocol, or the ETSI format could be used. The 5GAA Uu profile could also potentially be used to transfer the ETSI message.
18. The vehicle takes action (e.g. if a manually driven vehicle, the information is displayed and if it is an autonomous vehicle, the speed is adjusted).
19. The SP AS receives the IVIM and shares it with affected clients, e.g. ‘display information’.

The following table provides a matching of the above-described solution to SLRs defined as part of the user stories in [11]. SLRs highlighted in green are expected to be fulfilled according to comments giving in the comment column.

User story	Range [m]	Information requested/ generated	Service level latency [ms]	Service level reliability	Vehicle density [vehicle/km^2]	Comments
#1	1000	200-400B/message	2000	50%	10,000	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members
#2	1000	200-400B/message	2000	50%	500	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members
#3	1000	200-400B/message	2000	50%	5000	Expected to be feasible with framework demonstrated in large-scale trials like NORDIC WAY, planned by C-Roads members

#4	100,000	200-400B/message	Minutes	50%	10,000	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.
#5	200,000	200-400B/message	Minutes	50%	500	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.
#6	300,000	200-400B/message	Minutes	50%	5000	In commercial deployment, e.g. available via platforms from HERE, TOMTOM, INRIX, etc.

10 Conclusions, considerations and next steps

This document presents Use Case Implementation Descriptions (UCIDs) for the use cases Left-Turn Assist (LTA), (Electronic) Emergency Brake (Light) Warning (EEBL), and Traffic Jam Warning and Route Information. The document presents a framework for UCIDs, their integration into the 5GAA application layer reference architecture, and how they fit or match the SLRs defined in the use case descriptions [11]. Therefore, we consider this framework as template for further UCIDs.

The UCIDs in this Technical Report provide a first step to achieve greater information-sharing between actors by bringing together existing pieces (specifications, profiles, interface descriptions, etc.). Likewise, the descriptions provide guidance on how to leverage the benefits of combining C-V2X's multiple communication paths in order to realise the use cases. Although there are some limitations, restrictions and some open questions, the UCIDs do provide the baseline for follow-up discussions in other 5GAA WGs (e.g. regarding business-models and go-to market strategies, the C-V2X roadmap, or regarding interoperability and conformance testing). Similar to any large system development, there will always be a certain level of interpretation needed; implementations need to be iterated and tested to achieve interoperability and the target goal.

During the development of the UCIDs in this report, amongst others the following items were identified as being required for implementation purposes:

- Practical experience/feedback from implementation and/or field trials (e.g. to judge matching SLRs with a certain implementation option)
- Use case triggering conditions (e.g. available from other sources/organisations)
- Interface descriptions (e.g. which payload formats should be used for backend communication)
- Communication profiles (e.g. which parameters should be present for a certain use case)
- Additional message standards (e.g. how to exchange future trajectories in higher automation levels)
- Considerations how to ensure overall interoperability (e.g. how to ensure that different implementations are not just interoperable on the message level, but on overall system level, and to define required test plans)
- Considerations for the initialisation and discovery process (e.g. how to know in which area, which implementation option is available, and if multiple, which to use)
- Considerations to achieve/determine a minimum penetration (e.g. enabled vehicles, roadside units, consumer devices, supporting networks, etc,) to run the services

Note that these items are mostly unknown for more advanced use cases, which is also reflected in the gaps observed in the implementation description for the second user story for LTA, where 'higher automation levels are considered' and 'autonomous cars exchange planned, future trajectories with each other'. Discussions on the 'sensor sharing' use cases as well as the 'automated valet parking' (AVP) use cases in the C-V2X Roadmap II work item have underlined the need for robust use case implementation descriptions.

5GAA
Automotive Association