Automotive Association

# C-V2X Use Cases and Service Level Requirements Volume I

5GAA Automotive Association
Technical Report

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# Contents



# 1 Scope

The present report **represents the latest version of the first set** of Use Case (UC) descriptions (Volume 1 – previously named WAVE1) developed in the context of the 5GAA Working Group 1 (WG1) Work Item (WI) “Use Case and KPI requirements”[3]. The report introduces and explains the WG1 approach to describe Use Cases and their Service Level Requirements (SLRs). It includes a framework for the Use Case descriptions and one for Use Case SLR collection. The two frameworks are applied to the Use Cases provided in the 5GAA Board Internal Guidance Document [1].

The results and conclusions of this report serve as input for the work of other WGs in 5GAA, as well as sources for input and feedback for Standardisation activities, e.g. in 3GPP.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or nonspecific
- For a specific reference, subsequent revisions do not apply
- For a non-specific reference, the latest version applies


| | |
|---|---|
| [1] | 5GAA T-170024, "5GAA Board Internal Guidance Document: Vision and Principles," Barcelona, February 2017 |
| [2] | 5GAA T-170044, "Work Item Description: Use Case and KPI Requirements," Barcelona, Spain, February 2017 |
| [3] | 5GAA T-180065, "Work Item Description: Use Case and Service Level Requirements", Munich, Germany, February 2018 |
| [4] | 5GAA T-170060, Use Cases: Automotive View of Requirements |
| [5] | 5GAA T-170077, Definitions for C-V2X Use Case Framework |
| [6] | 5GAA T-170090, Use Case Descriptions |
| [7] | 5GAA T-170100, Use Case Framework, May 2017. |
| [8] | 5GAA T-170105, Daimler, Ford, "Proposal for a Common Template for Defining Use Cases in WG1," June 2017 |
| [9] | 5GAA T-170108, Denso, Huawei, Nokia, Intel, "On Road Environment, Use Cases and Scenarios: A Hierarchical Approach," June 2017 |
| [10] | 5GAA T-170109, Denso, Huawei, Nokia, Intel, "New Template for Use Cases Definitions," June 2017 |
| [11] | ETSI TR 102 638, "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions," June 2009 |
| [12] | 5GAA T-180101, "Extended Template for Use Cases Definitions," Intel, Denso, Ford, May 10, 2018 |
| [13] | 5GAA T-180004, "Service Level Requirements (SLRs) Table," 2018 |

# 3 Definitions and Abbreviations

## 3.1 Definitions

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

**Road Environments**: Road Environments are the typical places where vehicle traffic and C-V2X Use Cases occur, such as intersections, urban and rural streets, high-speed roads (autobahn), parking lots, etc.

**Use Cases**: Use Cases are the high-level procedures of executing an application in a particular situation with a specific purpose.

**User Stories**: User Stories are specific variations of one Use Case.

**Service Level Requirement (SLR):** SLRs describe solution-agnostic requirements of a Use Case.

## 3.2 Abbreviations

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

| | |
|---|---|
| BSM | Basic Safety Message |
| CAM | Cooperative Awareness Message |
| DENM | Decentralized Emergency Notification Message |
| ECU | Electronic Control Unit |
| HV | Host Vehicle |
| OEM | Original Equipment Maker |
| QoS | Quality of Service |
| RV | Remote Vehicle |
| UC | Use Case |
| VRU | Vulnerable Road User |
| WG | Woking Group |
| WI | Work Item |

# 4 Introduction

The present document contains the Use Case descriptions, the Use Case Service Level Requirements (SLRs), and corresponding frameworks developed in the context of the 5GAA WG1 Work Item T-180065 "Use Cases and KPI Requirements" [3] (revision/extension of [2]). WG1 took guidance from the board and described and analysed the Use Cases listed in the 5GAA Board Internal Guidance Vision and Principles document (T-170024) [1]. Note, previously, this set of Use Cases was also referred as WAVE1 Use Cases.

During this work, WG1 developed several documents containing existing and new technical definitions, scenario descriptions, and a common template for Use Case description.

- T-170060: Use Cases: Automotive View of Requirements [4]
- T-170077: Definitions for C-V2X Use Case Framework [5]
- T-170090: Use Case Descriptions [6]
- T-170105: Proposal for a Common Template for Defining Use Cases [8]
- T-170108: On Road Environment, Use Cases and Scenarios: A Hierarchical Approach [9]
- T-170109: New Template for Use Case Definitions [10]
- T-180101: Extended template for Use Cases Definitions [12]
- 5GAA T-180229: Intersection Movement Assist [13]

The remainder of this document is structured as follows. Section 5 introduces and describes the framework for C-V2X Use Case descriptions including SLRs. Section 6 contains the Use Case descriptions. Section 7 concludes the document.

# 5 C-V2X Use Cases Description Framework

## 5.1 Inter-relation between Road Environment, Use Cases, User Stories

The diverse Use Case requirements collected under 5GAA's WG1 and corresponding discussions and understandings they generated demand a similarly diverse response in terms of communication. Moreover, some concerns were raised regarding a common understanding of the differences between environments, Use Cases and User Stories (sometimes also referred to as Use Case scenarios). To tackle this problem several 'inter-relations' were introduced in [9].

In this section we present the relations between Road Environments, Use Cases and User Stories. First, we define those terms and then we show how they are connected.

1. **Road Environments:** Road Environments are the typical places where vehicle traffic and C-V2X Use Cases occur, such as intersections, urban and rural streets, high-speed roads (autobahn), parking lots, etc. Each Use Case should be mapped to at least one Road Environment, while the latter can be associated with one or more Use Cases. In combination, multiple Use Cases form the communication performance requirements in an environment. It should be noted that the preparation of an exhaustive list of Road Environments is not in the scope of the current WI in WG1.

2. **Use Cases:** Use Cases are the high-level procedures for executing an application in a particular situation with a specific purpose [1]. A Use Case may entail a number of specific User Stories, where different requirements may apply. 5GAA WG1 had studied 12 Use Cases initially recommended by the 5GAA Board, from which six have been prioritised for the development of the framework for requirement analysis. Note that one main goal of this hierarchical classification scheme is to describe Use Cases as 'atomic' units in order to reduce complexity. The rationale behind this approach is to define simple Use Cases rather than one combined complex Use Case.

3. **User Stories:** Given a high-level Use Case description as described above, different specific User Stories can be derived for different situations that may apply in different and yet specific requirements. For example, one Use Case may have a variation for driver assistance and another variant for fully automated driving.

Based on those definitions a three-level hierarchy can be defined, where in the highest level we have the Road Environment, in the middle level the Use Case and in the lowest level the User Stories.

The hierarchy and the relations between the different levels is exemplified in Figure 1:

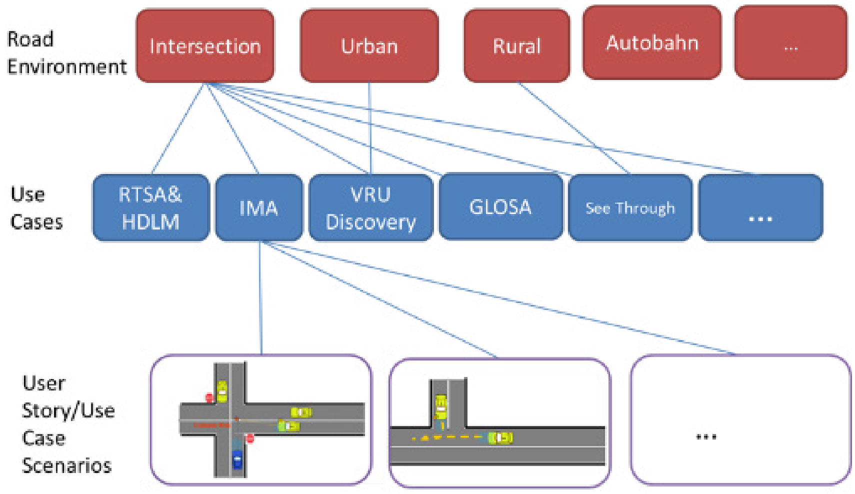



*Figure 1: Hierarchies*

We can observe that:

- Every Use Case is connected to at least one Road Environment and at least one Use Case scenario
- Every Road Environment may serve a framework to many Use Cases
- User Stories are specific variations of one Use Case

## 5.2 Template for Use Case Descriptions

It was agreed in WG1 that the Use Cases should be described in more detail following a template applicable to a wide range of Use Cases. An initial template for defining the Use Cases was proposed in [8].

Based on the initial template proposed in [8], an extended version was developed by WG1 [10] that allows a more detailed description of C-V2X Use Cases to support the derivation of the communications requirements. This template was further extended for the inclusion of multiple User Stories and corresponding SLRs in [13].

The objective of the template is to remain as abstract as possible relative to the specific implementation and architecture of the overlaying cellular system while defining specific roles for the different actors, the applicable Road Environment, and the specific Use Case scenario/User Story.

The template is presented in Table 1 with the corresponding explanation of the different fields. The use classification scheme is described in detail in Section 5.3. Table 2 contains the template for the User Stories, and Table 3 contains the template for corresponding SLRs. These SLRs are described in Section 5.4.

| | |
|---|---|
| **Use Case Name** | Name and abbreviation of the Use Case if existing. |

| | |
|---|---|
| **User Story** | Many User Stories can be defined for a single Use Case. Additionally, different User Stories could lead to the same requirements and the same system solution. It is not necessary and likely not practical to define all the User Stories initially and it is expected that more User Stories can be added later. |
| **Category** | Safety \| Vehicle Operations Management \| Convenience \| Autonomous Driving \| Platooning \| Traffic Efficiency and Environmental Friendliness \| Society and Community |
| **Road Environment** | Intersection \| Urban \| Rural \| Highway \| Other |
| **Short Description** | Short description of the Use Case. |
| **Actors** | Drivers, vehicles, traffic lights, VRUs, remote operators, application servers, ... including defining who the sending and receiving actor is (human, vehicle, or AV – automated vehicle, e.g. SAE automation levels 1-5 that are considered for the specific Use Case and may affect the performance requirements). |
| **Vehicle Roles** | Host Vehicle (HV) \| Remote Vehicle (RV) \| Other vehicle roles |
| **Roadside Infrastructure Roles** | Role of the road and traffic infrastructure (e.g. traffic signs, lights, ramps, etc.). Does not refer to the network infrastructure. |
| **Other Actors' Roles** | The role of other actors that are involved in this Use Case (e.g. VRU). |
| **Goal** | Goal of the Use Case. |
| **Needs** | The needs to be fulfilled in order to enable the Use Case. |
| **Constraints/ Presumptions** | Basic requirements that all actors need to adhere to. |
| **Geographic Scope** | Geographic areas where the Use Case is applicable. |
| **Illustrations** | Pictorial information exemplifying the Use Case and showing the role of the different actors. |
| **Pre-Conditions** | Necessary capability of the different actors to ensure the realisation of the Use Case. |
| **Main Event Flow** | Flow of events from the moment the Use Cases is triggered to the moment the Use Case closes. Includes the trigger point to enter and exit the Use Case (i.e. who and what). |
| **Alternative Event Flow** [1] | Alternative flow of events in case a different possibility exists.<br>Alternative event flows in this document are not intended as replacements for the main event flow.  They are intended to represent different possibilities. |
| **Post-Conditions** | Description of the output of flow clarifies which data is provided to the HV.<br>▸ Note 1: This data will trigger implementation-specific actions in the HV<br>▸ Note 2: This shall also be contained in the field information requirements |
| **Service Level Requirements** | Requirements to provide the service and taken from the list defined in Section 6. |
| **Information Requirements** | High-level description of information exchanged among involved actors (e.g. sensor data, kinematic data,...). |

*Table 1: Template for Use Case Descriptions*

| User Story | Detailed Description and Specifics |
|---|---|
| User Story #1 | |

[1] Alternative event flows in this document are not intended as replacements for the main event flow; they are intended to represent different possible flows.

| User Story #2 | |
|---|---|
| ..... | |

Table 2: Template User Stories

| User Story #1<br>Title of User Story (Optional) | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | | |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | | |
| **Service Level Latency** | **[ms]** | | |
| **Service Level Reliability** | **%** | | |
| **Velocity** | **[m/s]** | | |
| **Vehicle Density** | **[vehicle/km^2]** | | |
| **Positioning Accuracy** | **[m]** | | |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | | |
| **User Story #2<br>Title of User Story (Optional)** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | | |
| **Information requested/ generated** | **Quality of information/ Information needs** | | |
| **Service Level Latency** | **[ms]** | | |
| **Service Level Reliability** | **%** | | |
| **Velocity** | **[m/s]** | | |
| **Vehicle Density** | **[vehicle/km^2]** | | |
| **Positioning Accuracy** | **[m]** | | |
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | | |

Table 3: Template Service Level Requirements

## 5.3 Use Case Classification Scheme

This section introduces the categorisation/grouping view for the Use Cases, as introduced in [2]. As mentioned in [2], one goal is to more easily identify which stakeholder would benefit and have an incentive to drive the realisation of the Use Case and, optionally, participate in the financing of the UC. Additionally, the grouping of the UCs is supposed to simplify communication with other Working Groups, and aid their tasks, e.g. what to prioritise.

The Use Case grouping does not attempt to mirror or cover all Use Case categorisations carried out by numerous constellations carried out in different regions over recent decades. Instead, as a leading global organisation with worldwide representation, 5GAA aims to set a common language in this area which is also suitable for OEMs and their needs.

This approach also accommodates a number of new Use Cases emerging over recent years, so it is a good opportunity for a fresh (re)start for this area.

Another reason for making a fresh start and not simply copying current groupings is that most existing work, for example, uses descriptions from CVRIA (US DOT Connected Vehicle Reference Implementation Architecture) which are based on older technology, tend to be strongly associated with a specific region, and to some extent, comprise outdated Use Cases.

The following new groups were agreed in 5GAA WG1:

1. Safety
2. Vehicle Operations Management
3. Convenience
4. Autonomous Driving
5. Platooning
6. Traffic Efficiency and Environmental Friendliness
7. Society and Community

### 5.3.1 Safety

This group includes Use Cases that provide enhanced safety for vehicles and drivers. Examples of Use Cases include emergency braking, intersection management, assisted collision warning, and lane change.

These Use Cases would typically apply equally to autonomous vehicles or to provide assistance to drivers, with some notable exceptions such as ‘see-through’ camera assistance for human drivers.

It is expected that many of these Use Cases would need to be refined into a standard, regulated mode to ensure consistent operation and functioning between different OEMs. Potentially, legislation can be avoided if agreements to support a sufficient number of Use Cases can be agreed upon.

### 5.3.2 Vehicle Operations Management

This group includes Use Cases that provide operational and management value to the vehicle manufacturer. Use Cases in this group would include sensor monitoring, Electronic Control Unit (ECU) software updates, remote support, etc.

From a business and monetisation modelling point of view, these are Use Cases that could be provided by vehicle OEMs to improve the efficiency of vehicle maintenance, and vehicle monitoring. Some Use Cases, such as remote support, could possibly be sold to vehicle owners/drivers and transport/delivery companies.

These Use Cases are not likely to require standardisation, as each OEM could be developing them in their own proprietary mode. (Potentially, a group of OEMs could agree on a proprietary standard and implementation to save development cost for certain UCs.)

### 5.3.3 Convenience

This group includes Use Cases that provide value and convenience to the driver. Examples include infotainment, assisted and cooperative navigation, and autonomous smart parking. These are Use Cases that may not be mandated from a safety programme point of view, but which provide significant value to the driver or passengers in the vehicles.

From a business-modelling point of view, these are Use Cases that could be purchased by vehicle drivers or passengers.

### 5.3.4 Autonomous Driving

This Use Case group addresses Use Cases that are relevant for Autonomous/self-driving vehicles (level 4 and 5), and examples in this group are full control, if autonomous driving is allowed, tele-operation (potentially with Augmented Reality support), handling of dynamic maps (update/download), as well as some Safety UCs that require cooperative interaction between vehicles to be efficient and safe.

From a business modelling point of view, these Use Cases are of value to OEMs that can sell the features to vehicle owners/drivers, and transport/delivery companies.

### 5.3.5 Platooning

This group addresses Use Cases that are relevant for platooning, and examples cover a range of platoon management tasks, e.g. collect and establish a platoon, determine the position in platoon, dissolve a platoon, manage distance within platoon, leave a platoon, control the platoon in steady state, request passing through a platoon, etc.

These Use Cases are of interest to transport companies and potentially by road operators/road traffic authorities since road infrastructure could be used more efficiently, and also for society as it could provide environmental benefits such as reduced emissions, for example.

From a business modelling point of view, these Use Cases are valuable to OEMs that can sell the features to vehicle owners/drivers, and transport/delivery companies.

### 5.3.6 Traffic Efficiency and Environmental Friendliness

This group includes Use Cases that provide enhanced value to infrastructure or city providers, where the vehicles will be operating. Examples of this Use Case group include traffic light optimised speed advisory (sometimes also referred to as green light optimal speed advisory – GLOSA), traffic jam information, routing advice, e.g. smart routing.

From a business-modelling point of view, these Use Cases are of value to OEMs and service providers who can sell the features to vehicle owners/drivers and transport/delivery companies, and could potentially receive public subsidises, as there are environmental benefits involved.

### 5.3.7 Society and Community

This group includes Use Cases that are of value and interest to society and the public in general, e.g. public services such as road authorities, the police force, fire brigade and other emergency or government services. Examples in this group are emergency vehicles approaching, traffic light priority, patient monitoring, and crash reporting.

From a business-modelling point of view, these are of value to OEMs that can sell the features to the public/private sector.

## 5.4 C-V2X Use Case Requirements

### 5.4.1 Introduction

To be able to efficiently and systematically support a framework for characterising C-V2X Use Cases, 5GAA needs to ensure that all parties and working groups have a common set of definitions for dimensions used to describe the C-V2X Use Cases.

In line with the work split between WGs in 5GAA, this framework defines SLRs that describe Use Case requirements in a technology and implementation that takes place in an agnostic way. Note that this is an evolution of WG1's previous framework for such classifications.

The values of the SLRs always represent the upper bound and the most critical values, therefore they may be too strong for some instances of the use cases. Any use case with less critical requirements can therefore safely be implemented with the same values,

### 5.4.2 Service Level Requirements Definitions

This section contains the definitions of SLRs based on [13] and [14]. The SLRs are used to describe solution-agnostic requirements of the Use Case. In some instances, additional information has been provided to complement the definition.

- Range
  - Definition: Expected distance from HV to scenario application zone
  - Comments: N/A
  - Test: The Use Case test should include the distance equal to the range

between the HV and the scenario application zone

- Information requested/generated
  - Definition: Quality of information/information needs of the end-user (e.g. a driver, a passenger, robot in the car or remote driver, application programme running in an ECU, etc.). In this description, the end result of the information delivery is important while the actual transfer is not a concern
  - Comments/Examples:
    - Infotainment: Passengers are viewing a video stream with a certain resolution and a certain frame update rate
    - Software update: Vehicle needs to receive a software package of a given size within perhaps a deadline
    - Safety: Vehicle needs information on the precise location of other vehicles currently in its vicinity and in the near future
    - Quality of Information (QoI) in different contexts has the following attributes:
      - Timeliness
      - Appropriateness
      - Reliability
      - Accuracy
      - Completeness
      - Conciseness
      - Security
  - Test: The Use Case test should include, for example:
    - Size of the software update
    - Video signal quality
    - Enough information to determine the future dynamics of the vehicle
- Service Level Latency
  - Definition: Measurements of time from the occurrence of the event in a scenario application zone to the beginning of the resulting actuation. Depending on implementation, this includes one or more of the following:
    - Processing of the event into information by the information generator
    - Communication of the information to end-user
    - Processing of the information by the end-user
    - Time to actuation driven by the information processing results
  - Comments: It can be assumed that measurement of time starts when the information is generated. This requirement can be context-driven,

e.g. for see-through' we can request that video be available no more than 'T' after the need is expressed

- Test: The Use Case test should measure the time interval from the instant the information is requested/generated until the information is available at the destination

- Service Level Reliability
  - Definition: Based on an agreed QoS framework, the guaranteed and expected performance to start/initialise, perform and finalise (end-to-end) applications within Use Cases. Different agreed and provided QoS levels will result in different performances within the applications. Known or expected changes in Service Level Reliability before starting an application or during operation should be announced in a timely fashion (close to the relevant applications and entities involved)
  - Comments: N/A
  - Test: Tbd
- Velocity
  - Definition: Describes the maximum absolute speed of a vehicle at which a defined QoS can be achieved (in m/s). It describes the extent of the mobility and the average speed of the vehicle involved in the Use Case. Note that there may be a need to capture the peak expected speed. This definition may also be required to be split in order to describe the type of mobility from the speed. For instance, 'nomadic' is a type of mobility
  - Comments:
    - Typical speeds: Max. speed on highway 70 m/s or 36 m/s, Max. speed on rural road 27.8 m/s, Max. Speed in city: 19.5 m/s or 13.9 m/s or 8.4 m/s
    - Example reference: standardized speeds in urban areas, on rural roads, highways representing the upper bounds. The exception for this is Germany where there is no speed limit where for the estimation the averaged upper speed limit of German highways of 250km/h can be used
  - Test: The Use Case should be tested with vehicle speeds specified in this requirement
- Vehicle Density
  - Definition: Expected number of vehicles per given area (per km2) during the execution of the Use Case. Note that indicates that multiple vehicles within the same area run the same (and potentially additional) Use Case(s) in parallel
  - Comments:
    - Typical densities: Max. density on highway: 5,000, Max. density rural road: 9,000, Max. density in city: 12,000

    - Example calculation: 1 km², 5 m inter-vehicle spacing, fully congested scenario (downtown LA), two 20-lane highways crossing + 20 other lanes
    - Where possible, the comment field of this SLR should also contain the expected number of vehicles running the same use case per km2
  - Test: The Use Case should be tested with the vehicle density specified in this requirement. Note that this does not necessarily mean large number of vehicles; however, the impact of the vehicle density needs to be tested
- Positioning
  - Definition: Positioning/position/location accuracy at the time when position information is delivered to the end-user (HV), between the actual position and the position information
    - Location type: Absolute/geographical or relative or N/A
    - KPI: Accuracy level
  - Comments: How to measure accuracy and how to measure the error? Options are:
    - When the information is generated at the source
    - Or when the information is delivered to the HV (end-user)
  - Test: The Use Case is tested with at least the accuracy of positioning according to this requirement
- Interoperability/Regulatory/Standardisation Required
  - Definition: Yes/No, to indicate the need for inter-OEM interoperability, e.g. in cooperative safety Use Cases
  - Comments: N/A
  - Test: The Use Case shall be tested between different OEMs and/or different device manufacturers

### 5.4.3 Automotive View of C-V2X Use Case Requirements

The automotive view of C-V2X Use Cases requirements was initially collected in "T-170060: Use Cases: Automotive View of Requirements" [4]. The information in the document is intended as guidance for 5GAA WGs' work, e.g. for network architecture tasks. The document provides additional requirements on the different Use Case groups and individual Use Cases.

# 6 C-V2X Use Case Descriptions

This section contains description of the Use Cases developed by 5GAA WG1. According to the Use Case grouping introduced in [7], the Use Cases were classified into four groups: Safety, Convenience, Advanced Driving Assistance, and Vulnerable Road User (VRU). As shown in Figure 1, each Use Case can be composed of multiple User Stories, wherein each can differ in terms of road configuration, actors involved, service flows, etc. This grouping has been adjusted to represent the updated classification presented in section 5.3, where Advanced Driving Assistance has been replaced with Autonomous Driving.

This section includes Use Case descriptions developed and agreed within WG1. In addition to the Interim Report [12], four additional Use Case descriptions were added. Furthermore, all Use Cases were complemented with one or more User Stories, as well as corresponding SLRs.

The UC descriptions are written from the vehicle perspective and strive to be solution-agnostic and applicable to both driven and autonomous vehicles. The realisation of UCs does not preclude applications performing various tasks supporting the UCs, such as collecting information, analysing, etc. Furthermore, radio symbols in figures indicate a connected vehicle.

Note that it is also assumed that messages are exchanged in a secure way between authenticated parties.

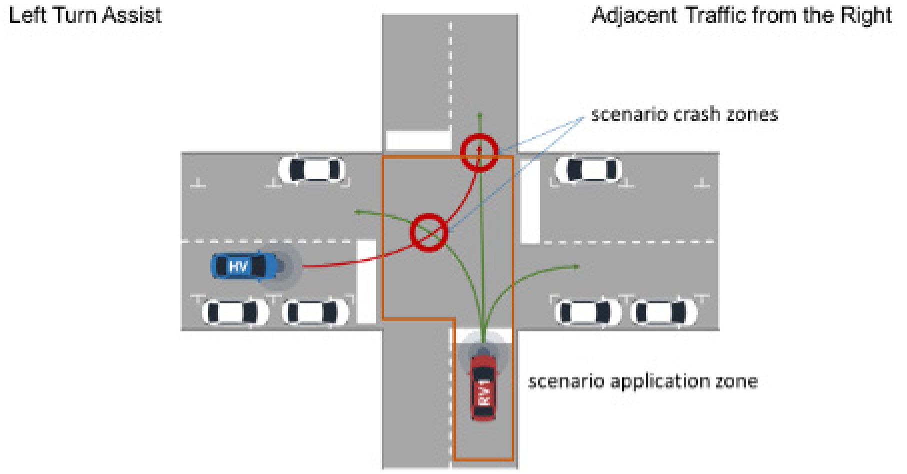
## 6.1 Safety

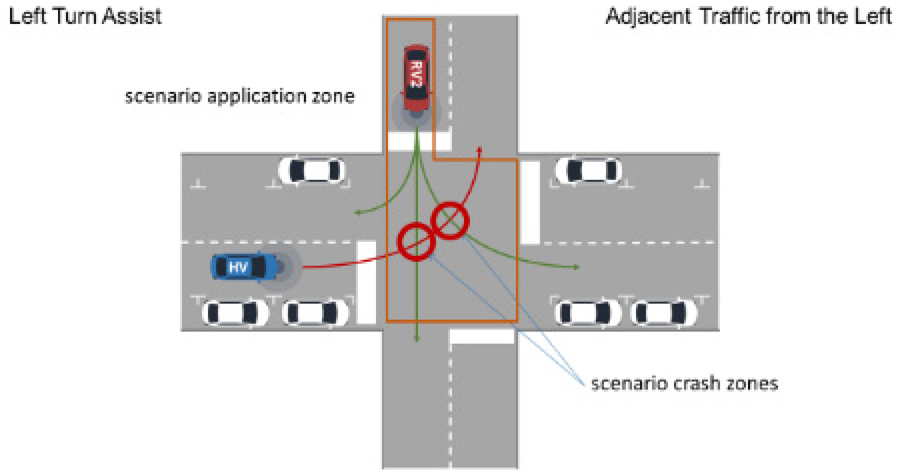
### 6.1.1 Cross-Traffic Left-Turn Assist

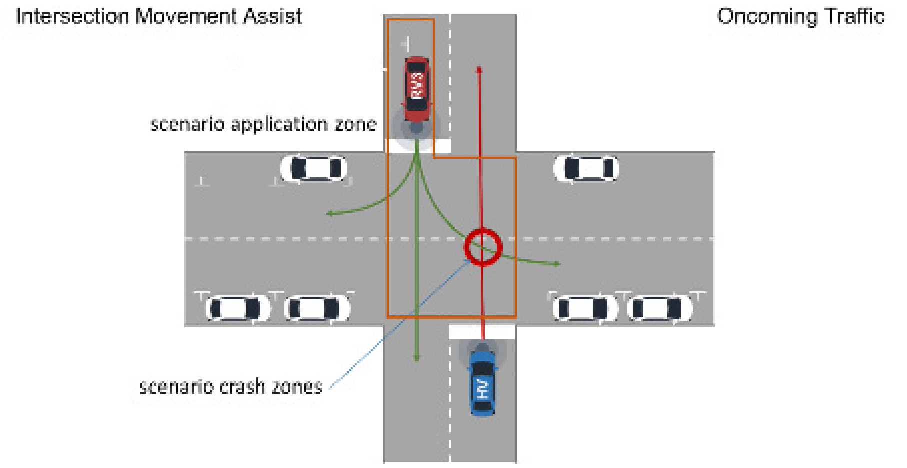
| | |
|---|---|
| **Use Case Name** | Cross-Traffic Left-Turn Assist |
| **User Story** | Assist HV attempting to turn left across traffic approaching from the opposite, left, or right direction |
| **Category** | Safety |
| **Road Environment** | Intersections, mostly for rural and outer city intersections, big metropolitan intersections to a lesser extent |
| **Short Description** | Alerts HV attempting to turn left across traffic of an RV approaching from the opposite direction in the lanes that HV needs to cross |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle 1 (RV1)<br>▸ Remote Vehicle 2 (RV2)<br>▸ Remote Vehicle 3 (RV3) |

| | |
|---|---|
| **Vehicle Roles** | ▸ HV represents the vehicle stopped at the intersection<br>▸ RV1 represents cross-traffic vehicle approaching from the right<br>▸ RV2 represents cross-traffic vehicle approaching from the left<br>▸ RV3 represents oncoming-traffic vehicle |
| **Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Intersections are defined by their crossing designations and geometry<br>▸ Traffic lights and stop signs control right of way traffic flow through an intersection (if available)<br>▸ Local traffic laws and rules control right of way through three-way stops, four-way stops, and unsigned intersections |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid a lateral collision between HV and RV1<br>▸ Avoid a lateral collision between HV and RV2<br>▸ Avoid an oncoming collision between HV and RV3 |
| **Needs** | ▸ HV needs to know if there is a risk of collision with RV1 approaching from the right<br>▸ HV needs to know if there is a risk of collision with RV2 approaching from the left<br>▸ HV needs to know if there is a risk of collision with an oncoming RV3 |
| **Constraints/ Presumptions** | ▸ RV1's intended direction through the intersection is known or can be estimated based on past values<br>▸ RV2's intended direction through the intersection is known or can be estimated based on past values<br>▸ RV3's intended direction through the intersection is known or can be estimated based on past values |
| **Geographic Scope** | Global |

**Illustrations**



| Pre-Conditions | ▸ HV is stopped at or moving towards an intersection<br>▸ HV signals its intention to turn left<br>▸ The 'Adjacent Traffic from the Right' scenario application zone is determined from:<br>– HV's location<br>– Lane designations and geometry<br>– Intersection geometry<br>– Posted speed limits<br>– Road conditions (if available)<br>▸ The 'Adjacent Traffic from the Left' scenario application zone is determined from:<br>– HV's location<br>– Lane designations and geometry<br>– Intersection geometry<br>– Posted speed limits<br>– Road conditions (if available)<br>▸ The 'Oncoming Traffic' scenario application zone is determined from:<br>– HV's location<br>– Lane designations and geometry<br>– Intersection geometry<br>– Posted speed limits<br>– Road conditions (if available) |
|---|---|

| Main Event Flow | ▶ RV1 is in the 'Adjacent Traffic from the Right' scenario application zone<br>▶ If RV1 has the right of way:<br>– RV1's trajectory through the intersection is estimated using:<br>– RV1's location and dynamics<br>– RV1's turn signal state<br>– Lane designations and geometry<br>– Intersection geometry<br>– HV's trajectory through the intersection is estimated using:<br>– HV's location<br>– HV's estimated acceleration<br>– Lane designations and geometry<br>– Intersection geometry<br>– If there is a risk of collision based on the estimated trajectories of HV and RV1 then:<br>– HV is warned of a risk of collision with RV1 approaching from the right<br>▶ Otherwise if HV has the right of way:<br>– RV1's stopping distance is estimated using:<br>– RV1's location and dynamics<br>– Lane designations and geometry<br>– Intersection geometry<br>– Road conditions (if available)<br>– If there is a risk that RV1 cannot stop before the intersection:<br>– HV is warned of a risk of collision with RV1 approaching from the right |
|---|---|

| | |
|---|---|
| **Alternative Event Flow** [2] | ▶ RV2 is in the 'Adjacent Traffic from the Left' scenario application zone<br>▶ If RV2 has the right of way:<br>– RV2's trajectory through the intersection is estimated using:<br>– RV2's location and dynamics<br>– RV2's turn signal state<br>– Lane designations and geometry<br>– Intersection geometry<br>– HV's trajectory through the intersection is estimated using:<br>– HV's location<br>– HV's estimated acceleration<br>– Lane designations and geometry<br>– Intersection geometry<br>– If there is a risk of collision based on the estimated trajectories of HV and RV2 then:<br>– HV is warned of a risk of collision with RV2 approaching from the left<br>▶ Otherwise if HV has the right of way:<br>– RV2's stopping distance is estimated using:<br>– RV2's location and dynamics<br>– Lane designations and geometry<br>– Intersection geometry<br>– Road conditions (if available)<br>– If there is a risk that RV2 cannot stop before the intersection:<br>– HV is warned of a risk of collision with RV2 approaching from the left |

2 Alternative Event Flows in this document are not intended as replacements for the Main Event Flow. They are intended to represent different possible flows.

| | |
|---|---|
| **Post-Conditions** | ▸ RV3 is in the 'Oncoming Traffic' scenario application zone<br>▸ If RV3 has the right of way:<br>– RV3's trajectory through the intersection is estimated using:<br>– RV3's location and dynamics<br>– RV3's turn signal state<br>– Lane designations and geometry<br>– Intersection geometry<br>– HV's trajectory through the intersection is estimated using:<br>– HV's location<br>– HV's estimated acceleration<br>– Lane designations and geometry<br>– Intersection geometry<br>– If there is a risk of collision based on the estimated trajectories of HV and RV3 then:<br>– HV is warned of a risk of collision with oncoming RV3<br>▸ Otherwise if HV has the right of way:<br>– RV3's trajectory and stopping distance is estimated using:<br>– RV3's location and dynamics<br>– RV3's turn signal state<br>– Lane designations and geometry<br>– Intersection geometry<br>– Road conditions (if available)<br>– If there is a risk that RV3 cannot stop before the intersection:<br>– HV is warned of a risk of collision with oncoming RV3 |
| **Service Level Requirements** | ▸ Positioning accuracy<br>▸ Information age<br>▸ Communications range |

| Information Requirements | <ul><li>HV's location</li><li>HV's turn signal state</li><li>HV's estimated acceleration from stopped</li><li>RV1's location and dynamics</li><li>RV1's turn signal state</li><li>RV2's location and dynamics</li><li>RV2's turn signal state</li><li>RV3's location and dynamics</li><li>RV3's turn signal state</li><li>Lane designations and geometry</li><li>Intersection geometry</li><li>Traffic stop signs</li><li>Traffic light signal phase and timing</li><li>Traffic rules and laws for three-way stops, four-way stops and unsigned intersections</li><li>Current road conditions (if available)</li></ul> |
|---|---|

| User Story | Detailed Description and Specifics |
|---|---|
| **User Story #1** | Automated vehicles exchange normal CAM messages. No information about future trajectories is exchanged. Instead, a risk for collision is calculated based on the data collected in the past and present and a warning is displayed to the driver, consecutively. |
| **User Story #2** | In this User Story, higher automation levels are considered. Autonomous cars exchange planned, future trajectories with each other. Based on those, more accurate estimation regarding possible collisions are possible. |

| User Story #1 (all scenarios, no matter which direction traffic is coming from) | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 300 | Maximum communication range assumed; this allows for ~5 s to react (at the max. speed mentioned within the velocity section). |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B per message | LTA in User Story one is based on normal CAM exchange. |
| **Service Level Latency** | **[ms]** | 100 | Normal CAM latency. |
| **Service Level Reliability** | % | 90 | For single CAM messages without retransmission, this reliability is enough to ensure the ETSI requirement of <5 % probability of two consecutive CAM message transmission failing. |
| **Velocity** | **[m/s]** | 28 | Most critical situations are to be expected at rural intersections. Here, the RV could be driving at up to 100 km/h, and the HV that wants to turn is slowing down, possibly also from 100 km/h. Therefore, maximum speeds of 100 km/h seem to be a reasonable value. |

| | | | |
|---|---|---|---|
| **Vehicle Density** | **[vehicle/km^2]** | 9000 | The most probable scenario for the Use Case is envisioned in rural intersections that are hard to see and where higher speeds of the participating cars are expected. |
| **Positioning Accuracy** | **[m]** | 1.5 (3 σ) | In order to perform lane-accurate positioning, a provisions of around 1 m should be made. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability between different OEMs is needed to the extent that every OEM should be able to receive signals broadcast by another OEM. Further interoperability is not needed.<br>Every vehicle should make its presence known periodically (as a broadcast).<br>Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood. |
| **User Story #2<br>(all scenarios, no matter which direction traffic is coming from)** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 300 | Maximum communication range assumed, this allows for ~5 s to react (at the max. speed mentioned within the velocity section). |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 1,000 B per message | Intended trajectories have to be sent by the RVs, since they determine whether or not a collision is imminent or not. In order to do so, some more payload than with normal CAMs should be used. |
| **Service Level Latency** | **[ms]** | 10 | LTA is a rather critical Use Case. Depending on the implementation, warning messages might be issued only shortly before actual turning is taking place. Therefore, this sort of a latency seems reasonable. |
| **Service Level Reliability** | % | 99.9 | A SLR this high should be enough to allow perceived zero-error appearance of the cross-traffic left-turn assist. False positives are more problematic than false negatives. |
| **Velocity** | **[m/s]** | 28 | Most critical situations are to be expected at rural intersections. Here, the RV could be driving with up to 100 km/h, and the HV that wants to turn is slowing down, possibly also from 100 km/h. Therefore, maximum speeds of 100 km/h seem to be a reasonable value. |
| **Vehicle Density** | **[vehicle/km^2]** | 9,000 | The most probable scenario for the Use Case is envisioned in rural intersections that are hard to see and where higher speeds of the participating cars are expected. |
| **Positioning Accuracy** | **[m]** | 1.5 (3 σ) | In order to perform lane-accurate positioning, a positioning accuracy of around 1 m should be provided. |

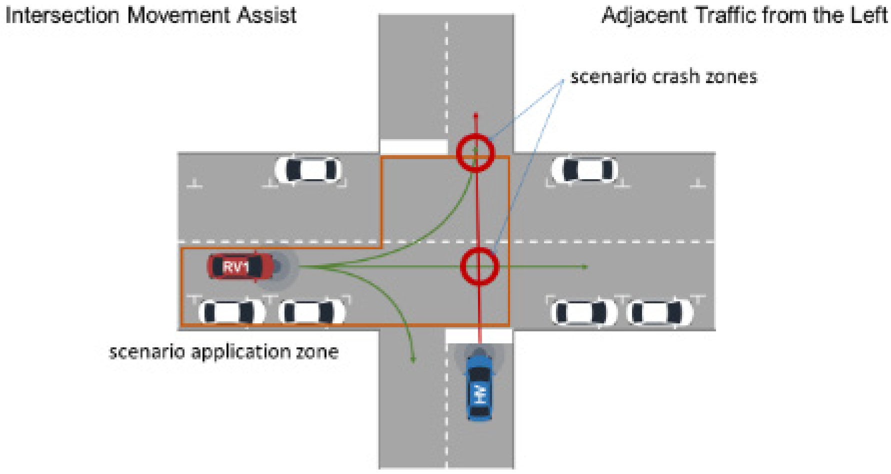
| | | | |
|---|---|---|---|
| **Interoperability Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability between different OEMs is needed.<br>Every vehicle should make its presence known periodically (as a broadcast).<br><br>Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood. |

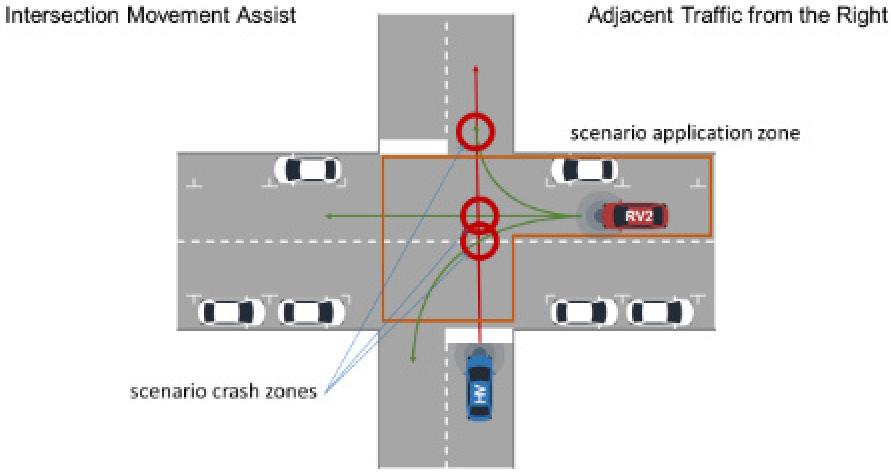
### 6.1.2 Intersection Movement Assist

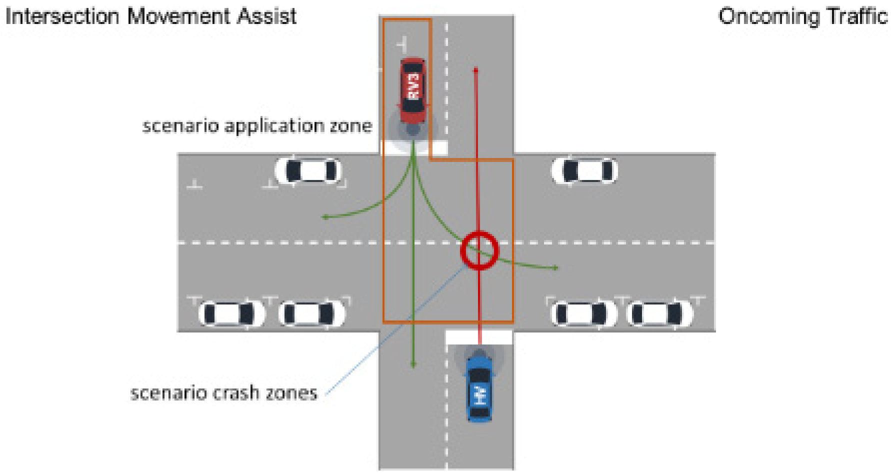
| | |
|---|---|
| **Use Case Name** | Intersection Movement Assist |
| **User Story** | Stationary HV proceeds straight from stop at an intersection. HV is alerted if it is unsafe to proceed through the intersection |
| **Category** | Safety |
| **Road Environment** | Intersections |
| **Short Description** | Alerts HV that is stopped and intending to proceed straight through the intersection of:<br>▸ Approaching cross-traffic from the left<br>▸ Approaching cross-traffic from the right<br>▸ Oncoming traffic intending to turn left |
| **Actors** | ▸ Host vehicle (HV)<br>▸ Remote Vehicle 1 (RV1)<br>▸ Remote Vehicle 2 (RV2)<br>▸ Remote Vehicle 3 (RV3) |
| **Vehicle Roles** | ▸ HV represents the vehicle stopped at intersection<br>▸ RV1 represents cross-traffic vehicle approaching from the left<br>▸ RV2 represents cross-traffic vehicle approaching from the right<br>▸ RV3 represents oncoming-traffic vehicle |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Intersections are defined by their crossing designations and geometry<br>▸ Traffic lights and stop signs control right of way traffic flow through an intersection (if available)<br>▸ Local Traffic laws and rules control right of way through three-way stops, four-way stops and unsigned intersections |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid a lateral collision between HV and RV1<br>▸ Avoid a lateral collision between HV and RV2<br>▸ Avoid an oncoming collision between HV and RV3 |
| **Needs** | ▸ HV needs to know if there is a risk of collision with RV1 approaching from the left<br>▸ HV needs to know if there is a risk of collision with RV2 approaching from the right<br>▸ HV needs to know if there is a risk of collision with an oncoming RV3 |

| | |
|---|---|
| **Constraints/ Presumptions** | ▸ The acceleration of HV from stopped must be assumed<br>▸ RV1's intended direction through the intersection is known<br>▸ RV2's intended direction through the intersection is known<br>▸ RV3's intended direction through the intersection is known |
| **Geographic Scope** | Global |

**Illustrations**



| | |
|---|---|
| **Pre-Conditions** | ▸ HV is stopped at an intersection.<br>▸ The 'Adjacent Traffic from the Left' scenario application zone is determined from:<br>– HV's location<br>– lane designations and geometry<br>– intersection geometry<br>– posted speed limits<br>– Road conditions (if available)<br>▸ The 'Adjacent Traffic from the Right' scenario application zone is determined from:<br>– HV's location<br>– lane designations and geometry<br>– intersection geometry<br>– posted speed limits<br>– Road conditions (if available)<br>▸ The 'Oncoming Traffic' scenario application zone is determined from:<br>– HV's location<br>– lane designations and geometry<br>– intersection geometry<br>– posted speed limits<br>– Road conditions (if available) |
| **Main Event Flow** | ▸ RV1 is in the 'Adjacent Traffic from the Left' scenario application zone.<br>▸ If RV1 has the right of way:<br>– RV1's trajectory through the intersection is estimated using:<br>  – RV1's location and dynamics<br>  – RV1's turn signal state<br>  – Lane designations and geometry<br>  – Intersection geometry<br>– HV's trajectory through the intersection is estimated using:<br>  – HV's location<br>  – HV's estimated acceleration<br>  – Lane designations and geometry<br>  – Intersection geometry<br>– If there is a risk of collision based on the estimated trajectories of HV and RV1 then:<br>  – HV is warned of a risk of collision with RV1 approaching from the left<br>▸ Otherwise if HV has the right of way:<br>– RV1's stopping distance is estimated using:<br>  – RV1's location and dynamics<br>  – Lane designations and geometry<br>  – Intersection geometry<br>  – Road conditions (if available)<br>– If there is a risk that RV1 cannot stop before the intersection:<br>  – HV is warned of a risk of collision with RV1 approaching from the left |

| Alternative Event Flow | |
|---|---|
| | ▸ RV2 is in the 'Adjacent Traffic from the Right' scenario application zone.<br>▸ If RV2 has the right of way:<br>– RV2's trajectory through the intersection is estimated using:<br>– RV2's location and dynamics<br>– RV2's turn signal state<br>– Lane designations and geometry<br>– Intersection geometry<br>– HV's trajectory through the intersection is estimated using:<br>– HV's location<br>– HV's estimated acceleration<br>– Lane designations and geometry<br>– Intersection geometry<br>– If there is a risk of collision based on the estimated trajectories of HV and RV2 then:<br>– HV is warned of a risk of collision with RV2 approaching from the right<br>▸ Otherwise if HV has the right of way:<br>– RV2's stopping distance is estimated using:<br>– RV2's location and dynamics<br>– Lane designations and geometry<br>– Intersection geometry<br>– Road conditions (if available)<br>– If there is a risk that RV2 cannot stop before the intersection:<br>– HV is warned of a risk of collision with RV2 approaching from the right |

| | |
|---|---|
| **Alternative Event Flow** | ▸ RV3 is in the 'Oncoming Traffic' scenario application zone<br>▸ If RV3 has the right of way:<br>– RV3's trajectory through the intersection is estimated using:<br>– RV3's location and dynamics<br>– RV3's turn signal state<br>– Lane designations and geometry<br>– Intersection geometry<br>– HV's trajectory through the intersection is estimated using:<br>– HV's location<br>– HV's estimated acceleration<br>– Lane designations and geometry<br>– Intersection geometry<br>– If there is a risk of collision based on the estimated trajectories of HV and RV3 then:<br>– HV is warned of a risk of collision with oncoming RV3<br>▸ Otherwise if HV has the right of way:<br>– RV3's trajectory and stopping distance is estimated using:<br>– RV3's location and dynamics<br>– RV3's turn signal state<br>– Lane designations and geometry<br>– Intersection geometry<br>– Road conditions (if available)<br>– If there is a risk that RV3 cannot stop before the intersection:<br>– HV is warned of a risk of collision with oncoming RV3 |
| **Post-Conditions** | ▸ HV is aware of a risk of collision with RV1 approaching from the left<br>▸ HV is aware of a risk of collision with RV2 approaching from the right<br>▸ HV is aware of a risk of collision with oncoming RV3 |
| **Service-Level KPIs** | ▸ Location accuracy<br>▸ Information age<br>▸ Communication range |

| | |
|---|---|
| **Information Requirements** | ▸ HV's location<br>▸ HV's turn signal state<br>▸ HV's estimated acceleration from stopped<br>▸ RV1's location and dynamics<br>▸ RV1's turn signal state<br>▸ RV2's location and dynamics<br>▸ RV2's turn signal state<br>▸ RV3's location and dynamics<br>▸ RV3's turn signal state<br>▸ Lane designations and geometry<br>▸ Intersection geometry<br>▸ Traffic stop signs<br>▸ Traffic light signal phase and timing<br>▸ Traffic rules and laws for three-way stops, four-way stops and unsigned intersections<br>▸ Current road conditions (if available) |

| User Story | Detailed Description and Specifics |
|---|---|
| **User Story #1** | Two vehicles are approaching an intersection (as described in main event flow). The vehicles determine the risk for a collision based on the vehicles' estimated trajectories. |

| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 100 | Braking distance from 100 km/h, e.g. at an intersection on a rural road. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B per message | Calculate trajectories based on exchanged data in BSM or CAM. Changes in kinematics of involved vehicles might require this information to be updated (or shared periodically) within the boundaries given by the Service Level Latency. |
| **Service Level Latency** | **[ms]** | 100 | Not highly time critical, but should stay below 100 ms to be effective/comparable to other ADAS. |
| **Service Level Reliability** | **%** | 99.99 | Needs to reliably allow for trajectory calculation to avoid collisions. |
| **Velocity** | **[m/s]** | 28 | Assuming speeds up to 100 km/h. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum assumed density in urban situation. |
| **Positioning Accuracy** | **[m]** | 1.5 (3 σ) | Required for accurate trajectory calculation and collision risk estimation in relation to vehicle size. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability between manufacturers' implementations to be guaranteed by standardisation. |

### 6.1.3 Emergency Brake Warning

| | |
|---|---|
| **Use Case Name** | Emergency Brake Warning |
| **User Story** | Alert HV that a lead RV is undergoing an emergency braking event |
| **Category** | Safety |
| **Road Environment** | Urban \| Rural \| Highway |
| **Short Description** | Alert HV if a lead vehicle is braking |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle (RV) |
| **Vehicle Roles** | ▸ HV represents the vehicle approaching the lead vehicle from behind<br>▸ RV1 represents the lead vehicle that has applied its brakes |
| **Road and Roadside Infrastructure Roles** | ▸ N/A |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid a rear end collision between HV and RV |
| **Needs** | HV needs to know if there is an emergency braking event in RV |
| **Constraints/ Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's safe following distance<br>– HV's safe stopping distance<br>– RV's safe stopping distance is same as HV's |
| **Geographic Scope** | Global |

**Illustrations**

Emergency Brake Warning – No Congestion

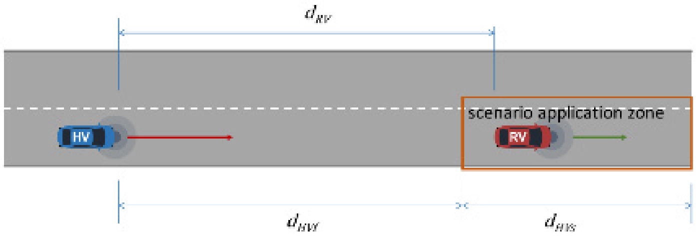
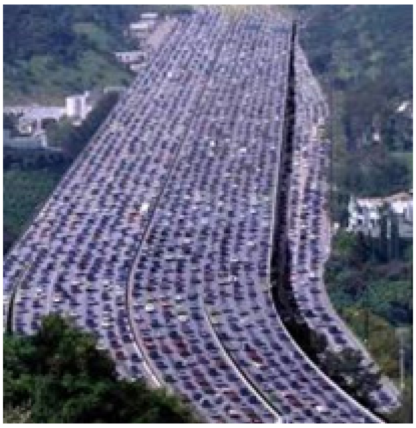
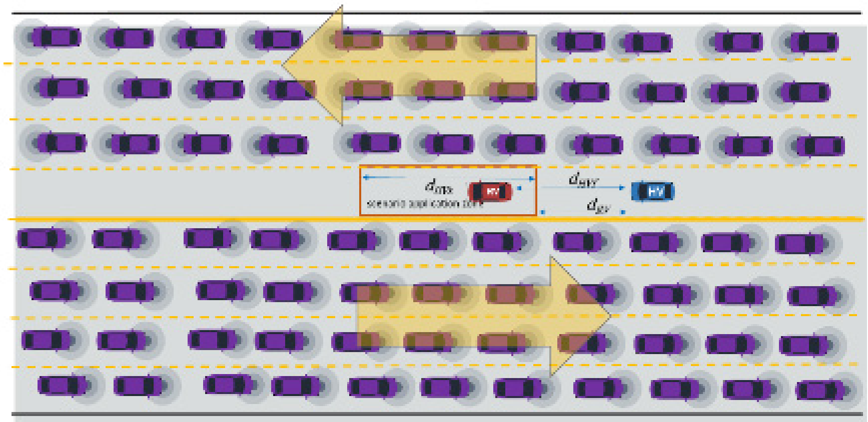



Illustration of high congestion



Emergency Brake Warning – Congestion




- $d_{RV}$= distance between HV and RV
- $d_{HVf}$= safe following distance of HV
- $d_{HVs}$= safe stopping distance of HV

| | |
|---|---|
| **Pre-Conditions** | ▸ HV is following RV<br>▸ The 'Emergency Brake Warning' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe following distance<br>– HV's safe stopping distance<br>– Lane designations and geometry<br>– Current road conditions (if available) |
| **Main Event Flow** | ▸ RV applies the brakes<br>▸ If RV is in 'Emergency Brake Warning' scenario application zone<br>a. HV is alerted of the braking event in a leading RV |
| **Post-Conditions** | ▸ HV is aware of a braking event in a leading RV |
| **Service Level Requirements** | ▸ Positioning<br>▸ Latency<br>▸ Range<br>▸ Vehicle density |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's safe following distance<br>▸ HV's safe stopping distance<br>▸ RV's location and dynamics<br>▸ Lane designations and geometry<br>▸ Current road conditions (if available) |

| User Story | Detailed Description and Specifics |
|---|---|
| **User Story #1** | HV is moving at very high speed which is different from the RV in a highly congested traffic scenario illustrated above. HV is driven by human driver. RV applies the brakes in order to make an emergency stop. HV is at distance *d* behind the RV and the HV driver does not see RV applying brakes or is distracted. Wet road conditions assumed. |
| **User Story #2** | HV is at least Level 2. HV is moving at very high speed which different from the RV in a highly congested traffic scenario illustrated above. HV is driven by human driver or robot. RV applies brakes in order to make an emergency stop. Wet road conditions assumed. |

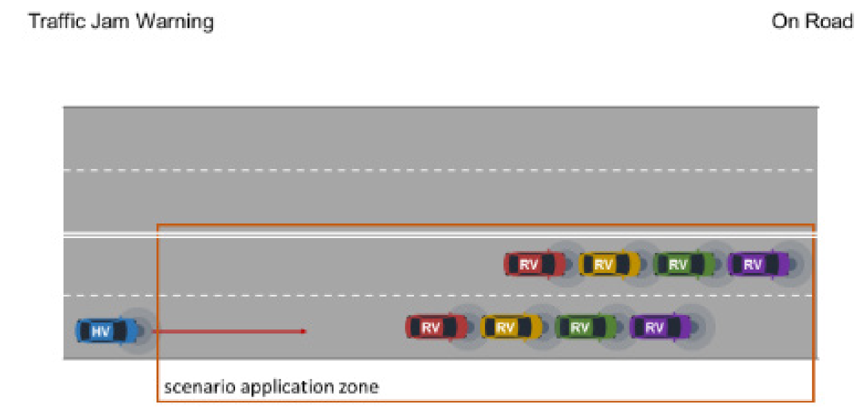
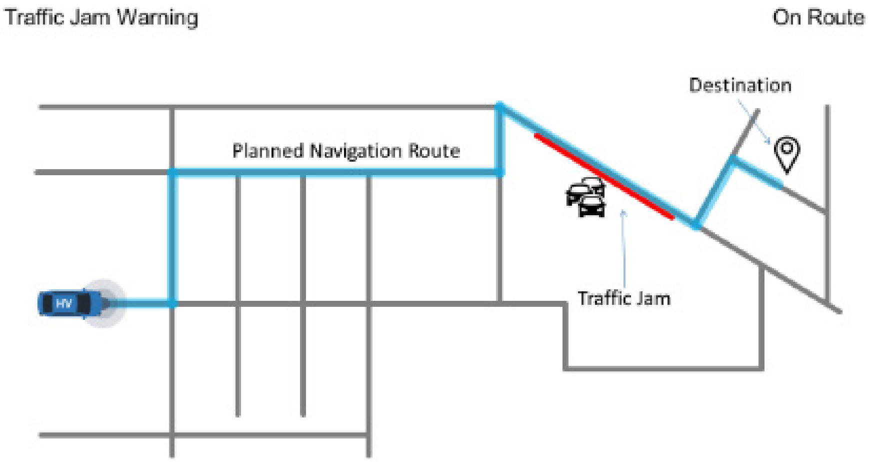
| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 360 | Under the assumptions of Vrv=25 m/s, Vhv=50 m/s and a=0.4g this is the minimum distance (400 ms margin or 20 m) at which HV needs to be warned to avoid collision. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 200-400 B per message | The message should be delivered to HV. It contains the information about the hard-braking event at RV. It contains other information regarding RV such as location, velocity, acceleration, etc. |

| | | | |
|---|---|---|---|
| **Service Level Latency** | **[ms]** | 120 | Ideally, the information about the hard-braking event should be conveyed as soon as possible. Examining current radar and camera vision sensors the detection times are 100-300 ms which makes V2X latency within the same budget. Additionally, for the reliability that we are requesting this latency seems reasonable. For example, the latency of 100 ms causes the HV to travel additional 5 m before final stop at 50 m/s initial velocity, however, this additional distance is budgeted in the range estimate.<br>This includes handling, access, and Over-The-Air latency. |
| **Service Level Reliability** | **%** | 99.99 | The hard-braking event message needs to be delivered to the HV with high reliability. |
| **Velocity** | **[m/s]** | 36 | Assuming highway speeds. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city scenario. |
| **Positioning Accuracy** | **[m]** | 1.5 (3▯) | HV needs to know whether the hard-braking vehicle in the front is in the same lane. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability needs to be in place for HV to receive a message from RV. |
| **User Story #2** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 290 | Under the assumptions of Vrv=25 m/s, Vhv=50 m/s, 0.5 s reaction time and a=0.4 g (and 300 ms margin or 15 m) this is the minimum distance at which the Level 3 system needs to be warned to avoid collision. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 200-400 B per message | The message should be delivered to HV. It contains the information about the hard-braking event at RV. It contains other information regarding RV such as location, velocity, acceleration, etc. |
| **Service Level Latency** | **[ms]** | 120 | Reasonable latency in the context of the other existing sensor systems as well as taking into account the high reliability needed. |
| **Service Level Reliability** | **%** | 99.99 | The hard-braking event message needs to be delivered to the HV with high reliability. |
| **Velocity** | **[m/s]** | 36 | Assuming highway speeds. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density. |
| **Positioning Accuracy** | **[m]** | 1.5 (3▯) | HV needs to know whether the hard-braking vehicle in the front is in the same lane. |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability needs to be in place for HV to receive a message from RV. |

### 6.1.4 Traffic Jam Warning and Route Information

| | |
|---|---|
| **Use Case Name** | Traffic Jam Warning and Route Information |

| | |
|---|---|
| **User Story** | Alert the HV when approaching (the end of) a traffic jam or a road blockage on route. |
| **Category** | Safety |
| **Road Environment** | Urban \| Rural \| Highway |
| **Short Description** | ▸ Warn HV when approaching (the end of) a traffic jam on the road<br>▸ Notify HV of a traffic jam on the navigation route<br>▸ Any kind of cause for this situation can be considered, such as disaster situations |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle (RV) |
| **Vehicle Roles** | ▸ HV represents vehicle approaching (the end of) a traffic jam<br>▸ RVs represent vehicles in traffic jam |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Alert HV when approaching (the end of) a traffic jam |
| **Needs** | HV need to be aware when approaching (the end of) a traffic jam and its geometry |
| **Constraints/ Presumptions** | ▸ N/A |
| **Geographic Scope** | Global |

| | |
|---|---|
| **Illustrations** | <br> |
| **Pre-Conditions** | ▸ HV is moving forward<br>▸ Known traffic jam is defined by its location and geometry<br>▸ The 'On Road' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe stopping distance<br>– Lane designations and geometry<br>– Road conditions (if available)<br>▸ The 'On Route' scenario application zone is determined from:<br>– HV's location<br>– HV's planned navigation route |
| **Main Event Flow** | ▸ If the traffic jam's location is in the 'On Road' scenario application zone:<br>– Warn HV when approaching the end of the traffic jam |

| | |
|---|---|
| **Alternate Event Flow** | ▸ If the traffic jam's location is in the 'On Route' scenario application zone:<br>– Notify HV of the traffic jam location and geometry |
| **Post-Conditions** | ▸ HV is aware of the (end of) the traffic jam on the road<br>▸ HV is aware of the traffic jam's location and geometry on the navigation route |
| **Service Level Key Performance Indicators** | ▸ Communications range<br>▸ Age of information<br>▸ Position accuracy |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's safe stopping distance<br>▸ HV's planned navigation route (if available)<br>▸ Lane designations and geometry<br>▸ Traffic jam's location and geometry |

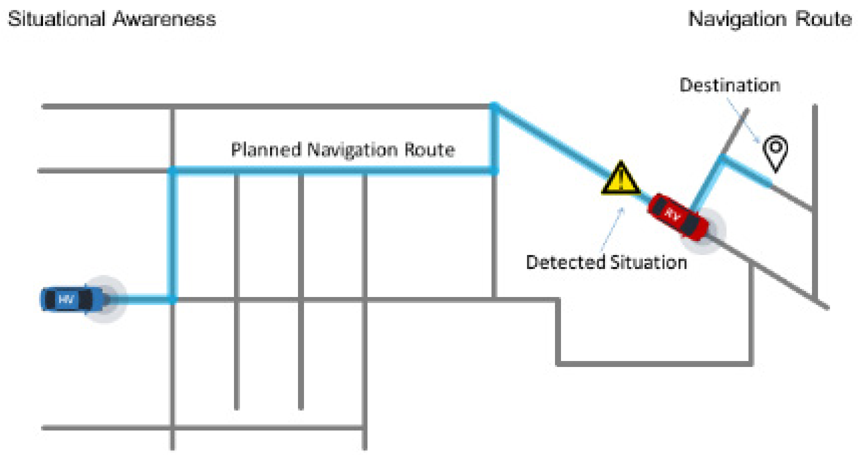
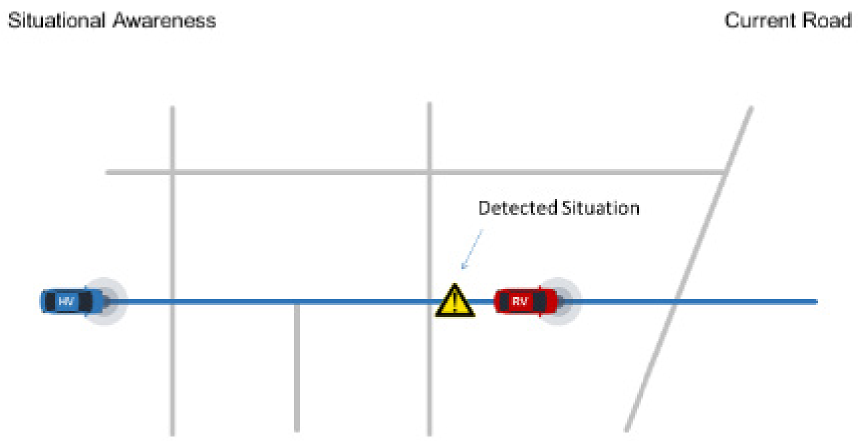
| User Story | Detailed Description and Specifics |
|---|---|
| **#1: Traffic jam on road** | The HV is warned of the end of a traffic jam ahead on the road |
| **#2: Traffic jam on route** | HV is informed of a traffic jam on its (navigation) route |

| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 400 | Calculation based on estimated braking to full stop distance at maximum velocity of 250 km/h, assuming 1s reaction time and deceleration of 7.7 m/s. (70m/s*1s+(70m/s)^2/2*7.7m/s^2) |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B per message | Get traffic jam information from BSM or DENM, or similar message.<br>Size usually around 300 B. |
| **Service Level Latency** | **[ms]** | 100 | Assuming above mentioned calculation for breaking time, 100ms appears adequate. |
| **Service Level Reliability** | % | 99.99 | |
| **Velocity** | **[m/s]** | 70 | 250 km/h on highways. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum assumed density in urban situation. |
| **Positioning Accuracy** | **[m]** | < 20 | As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than Line of Sight (LoS) the given values seem reasonable. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability between manufacturers' implementations to be guaranteed by standardisation. |

| User Story #2<br>Urban Scenario on Route Information | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 300,000 | Warn early enough to safely brake when approaching the traffic jam.<br>Calculation based on the duration of a traffic jam and the possibility for it to still exist when a vehicle driving on its way with an average speed is reaching the jam (duration 2 h, speed 50 km/h, 100 km/h 150 km/h). |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B per message | Get traffic jam information from BSM or DENM, or similar message.<br>Size usually around 300 B. |
| **Service Level Latency** | **[ms]** | Minutes | Traffic jams are normally not happening within a very short time period. If communication range is big enough e.g. on a highway 2 seconds driving with 150 km/s means 80 m. Jam should be visible if you are as close as 80 meters in urban environment (50 km/h), 2 s means 26 m which should be close enough to see the jam |
| **Service Level Reliability** | **%** | 99 | |
| **Velocity** | **[m/s]** | 70 | 250 km/h on highways. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum assumed density in urban situation. |
| **Positioning Accuracy** | **[m]** | < 20 | As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than LoS the given values seem reasonable. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability between manufacturers' implementations to be guaranteed by standardisation. |

### 6.1.5 Hazardous Location Warning

| | |
|---|---|
| **Use Case Name** | Hazardous Location Warning |
| **User Story** | An HV is driving on a road (route), heading towards a road segment, which presents unsafe and unknown conditions ahead. The HV is made aware of situations detected and shared by RVs. Situations may include any location presenting risks such as accidents, weather, traffic, construction |
| **Category** | Safety \| Automated Driving |
| **Road Environment** | Urban \| Rural \| Highway |
| **Short Description** | ▸ An HV is made aware of locations with accidents, traffic, adverse weather, road conditions, construction and other situations detected and shared by RVs. The shared locations are relevant along the HVs navigation route or current road of travel. Some examples include but are not limited to:<br>▸ Traffic congestion area detected by slowly-moving RVs<br>▸ Adverse weather condition areas detected by temperature changes and wiper activation<br>▸ Accident areas detected by air bag deployment events<br>▸ Slippery road condition areas detected by traction control events<br>▸ Disabled vehicles detected by hazard lamps or tyre pressure areas<br>▸ Dangerous curves<br>▸ Animal on the road<br>▸ Surface conditions<br>▸ Obstacle on the road |
| **Actors** | ▸ Remote Vehicle (RV).<br>▸ Host Vehicle (HV). |
| **Vehicle Roles** | ▸ RV represents the vehicle detecting and sharing situational information<br>▸ HV represents the vehicle made aware of situational information |
| **Road and Roadside Infrastructure** | ▸ Roads are defined by their lane designations and geometry |
| **Other Actors' Roles** | Traffic management: An entity that collects accidents, traffic, adverse weather, road conditions, construction and other situations and reports them to other vehicles. (For User Story 2, not for 1) |
| **Goal** | ▸ Alert HV of a situation that lies ahead along its navigation route or current road segment |
| **Needs** | HV needs to be aware of a situation that lies ahead along its navigation route or road segment |
| **Constraints/ Presumptions** | ▸ The 'Navigation Route' scenario includes all roads ahead along HV's known navigation route<br>▸ The 'Current Road' scenario includes the length of the road ahead that HV is currently travelling on |
| **Geographic Scope** | Everywhere |

| | |
|---|---|
| **Illustrations** | <br><br><br> |
| **Pre-Conditions** | ▸ One or more RV's have detected conditions that constitute a situation that HV should be made aware of |
| **Main Event Flow** | ▸ If the situation's location is on HV's navigation route:<br>– One or more RV's have reported conditions to the Traffic Management entity that constitute a situation that one or more HVs should be made aware of<br>– HV is made aware of the situation's nature and location (cf. User Story #2) |
| **Alternate Event Flow** | ▸ If the situation's location is ahead along HV's current road of travel:<br>– One or more RV's detect a situation that one or more HVs should be made aware of<br>– The RV(s) provide the notification to the HV(s)<br>– HV is made aware of the situation's nature and location |
| **Post-Conditions** | ▸ HV is made aware of a detected situation along its navigation route or current road ahead |

| | |
|---|---|
| **Service Level KPIs** | ▸ Service Level Latency<br>▸ Service Level Reliability<br>▸ Information requested/generated<br>▸ Velocity<br>▸ Vehicle density<br>▸ Positioning accuracy |
| **Information Requirements** | ▸ RV's location and dynamics<br>▸ RV's wiper, lamps status<br>▸ RV's outside temperature, barometric pressure<br>▸ RV's hazard lamps, tyre pressure<br>▸ RV's ABS, stability control, traction control, airbag events<br>▸ Road map<br>▸ HV's navigation route<br>▸ Road conditions<br>▸ Construction zone map |

| User Story | Detailed Description and Specifics |
|---|---|
| **User Story #1**<br>**Hazardous location on road** | An RV is driving on the road and approaches a dangerous area which is detected by using RV's sensors. The HV might drive behind the RV in the same direction, or in front of the RV in the opposite direction, so towards the area where the RV has detected the dangerous situation. RVs detecting such dangerous situations will share information about them to other vehicles, e.g. the HV.<br>The HV or HV driver can assume appropriate actions after having received the awareness information (also depending on if the hazard is in the same lane or in a different lane as the HV). |
| **User Story #2**<br>**Hazardous location on route** | This user story is linked to a real-time HD map update service. The HV is receiving information that is relevant for the route ahead (e.g. from a backend), containing information that might allow the HV to adjust its route accordingly. The traffic management mentioned in 'Other Actors' Roles' could be significant here. |

| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 400 | Calculation based on estimated braking to full stop distance at maximum velocity of 250 km/h, assuming 1 s reaction time and deceleration of 7.7 m/s. (70m/s*1s+(70m/s)^2/2*7.7m/s^2) |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B | Normal size of CAM/BSM should be enough, maybe containing fields indicating common types of critical situations that lie ahead. Transmission of detailed object information is not needed. Standard transmission rate of 10 Hz should be enough. |
| **Service Level Latency** | **[ms]** | 100 | Driving with 120 km/h, 300 m (minimum communication range) will take just short of 10 s, so 100 ms for the car to react should be enough. |
| **Service Level Reliability** | **%** | 99 | The HV could aggregate warnings from several RVs, each individual RVs reliability thus does not have to be too high. |

| | | | |
|---|---|---|---|
| **Velocity** | **[m/s]** | 70 | ~250 km/h – Max speed on highways, also realistic for relative speeds of HV and RV driving in different directions. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Typical positioning accuracy to confirm traffic lane. (For non-lane-specific information, less accurate localisation is acceptable.) |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Inter-OEM-operability must be assured. |
| **User Story #2** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 30,000 | Situations are relevant along a navigation route or along a road if a navigation route is not known. Depends on the needs for efficient re-routing. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300-1000 B | From the backend, the HV will receive information (events, or vector data), not raw data. Some details are needed, but still no need for detailed object descriptions or the like. |
| **Service Level Latency** | **[ms]** | 1-2 s<br>10-200 s | Information may need to be aggregated from multiple RVs before a situation is identified.1-2 s for safety-related information concerning the vicinity of the HV; 10-200 s for general information about route obstructions or the like further ahead, in order to make timely rerouting possible. |
| **Service Level Reliability** | **%** | 99 | For safety-related information, timely and reliable communication is decisive.<br>In the backend, data of several vehicles is aggregated, so the single vehicle's data has to be moderately reliable. For rerouting information, this should be enough. |
| **Velocity** | **[m/s]** | 70 | ~250 km/h – max. speed on highways. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum density in city. |
| **Positioning Accuracy** | **[m]** | 0.5<br>< 5 | Typical positioning accuracy to confirm traffic lane.<br>For non-lane-specific information, less accurate localization is acceptable. |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes | Inter-vendor-operability must be assured. |

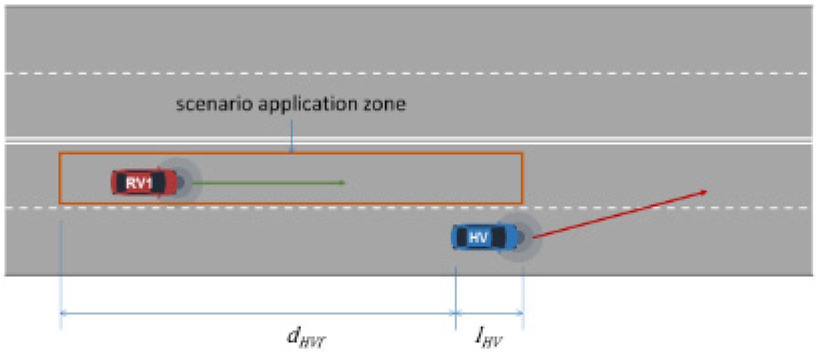
### 6.1.6 Lane Change Warning

| | |
|---|---|
| **Use Case Name** | Lane Change Warning |
| **User Story** | HV signals an intention to change lanes |
| **Category** | Safety |
| **Road Environment** | Urban \| Rural \| Highway |

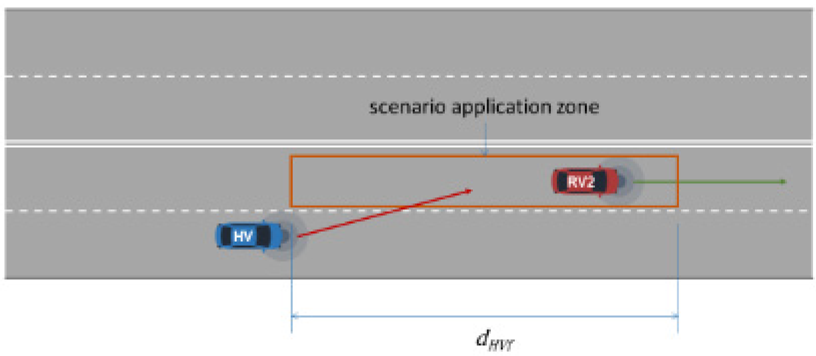
| | |
|---|---|
| **Short Description** | ▸ Alert HV intending to change lanes of a lack of space or risk of collision with a lagging RV1 approaching from behind in the target lane<br>▸ Alert HV intending to change lanes of a lack of space or risk of collision with a leading RV2 in the target lane<br>▸ Alert HV intending to change lanes that this manoeuvre is not permitted on the current road segment |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle 1 (RV1)<br>▸ Remote Vehicle 2 (RV2) |
| **Vehicle Roles** | ▸ HV represents the vehicle intending to change lanes<br>▸ RV1 represents the lagging vehicle in the target lane<br>▸ RV2 represents the leading vehicle in the target lane |
| **Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Road segments indicate where changing lanes is not permitted |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid HV encroaching into RV2; avoid HV encroaching into RV1 |
| **Needs** | ▸ HV needs to know if there is a lack of space or risk of collision with a lagging RV1 in the target lane<br>▸ HV needs to know if there is a lack of space or risk of collision with a leading RV2 in the target lane<br>▸ HV needs to know if a lane change is not permitted on the current road segment |
| **Constraints/ Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's safe following distance<br>– RV1's safe following distance is the same as HV's. |
| **Geographic Scope** | Global |

| Illustrations | |
| --- | --- |

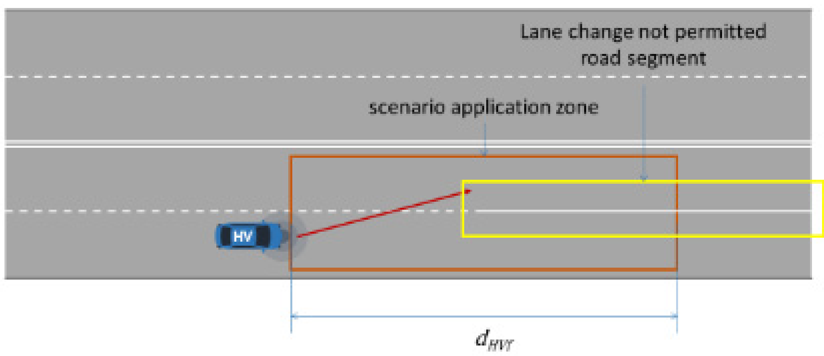
Lane Change Warning — Lagging Vehicle




Lane Change Warning — Leading Vehicle




Lane Change Warning — Not Permitted




- $d_{HVf}$ = safe following distance of HV
- $l_{HV}$ = lenght of HV

| | |
|---|---|
| **Pre-Conditions** | ▸ HV has signalled its intention to change lanes<br>▸ Known road segments define is passing is not permitted<br>▸ The 'Lagging Vehicle' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's length<br>– HV's safe following distance<br>– Lane designations and geometry<br>– Road conditions (if available)<br>▸ The 'Leading Vehicle' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe following distance<br>– Lane designations and geometry<br>– Road conditions (if available) |
| **Main Event Flow** | ▸ If RV1 is in the 'Lagging Vehicle' scenario application zone:<br>– If the trajectory of RV1 and HV cross:<br>– Warn HV of the risk of collision with RV1<br>– Otherwise:<br>– Alert HV of the lack of space to safely complete the manoeuvre |
| **Alternative Event Flow [3]** | ▸ If RV2 is in the 'Leading Vehicle' scenario application zone:<br>– If the trajectory of RV2 and HV cross:<br>– Warn HV of the risk of collision with RV2<br>– Otherwise:<br>– Alert HV of the lack of space to safely complete the manoeuvre. |
| **Alternative Event Flow** | ▸ If a road segment where passing is not permitted is in the 'Not Permitted' scenario application zone<br>▸ Warn HV that a lane change manoeuvre is not permitted in the current road segment |
| **Post-Conditions** | ▸ HV is aware of a lack of space or of a risk of collision with a lagging RV1 in the target lane<br>▸ HV is aware of a lack of space or of a risk of collision with a leading RV2 in the target lane<br>▸ HV is aware of whether a lane change is permitted or not on the current road segment |
| **Service Level Requirements** | ▸ Positioning accuracy<br>▸ Information age<br>▸ Communication range<br>▸ Duration of the communication |

3 Alternative Event Flows in this document are not intended as replacements for the Main Event Flow. They are intended to represent different possible flows.

| Information Requirements | ▸ HV's location and dynamics<br>▸ HV's length<br>▸ HV's safe following distance<br>▸ RV1's location and dynamics<br>▸ RV2's location and dynamics<br>▸ Lane designations and geometry<br>▸ Road segment lane change rules<br>▸ Road conditions (if available) |
|---|---|

| User Story | Detailed Description and Specifics |
|---|---|
| User Story #1 | This User Story presents the warning to the HV that a vehicle is approaching from behind in the lane the HV plans to change into. |
| User Story #2 | This Lane Change User Story here represents the warning when HV is merging into a lane where a vehicle ahead is driving at lower speeds. |
| User Story #3 | This User Story takes place when the HV intends to change into a lane but does not have permission to do so due to for example road markings. |

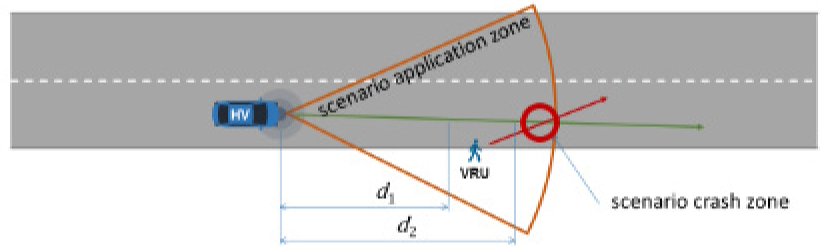
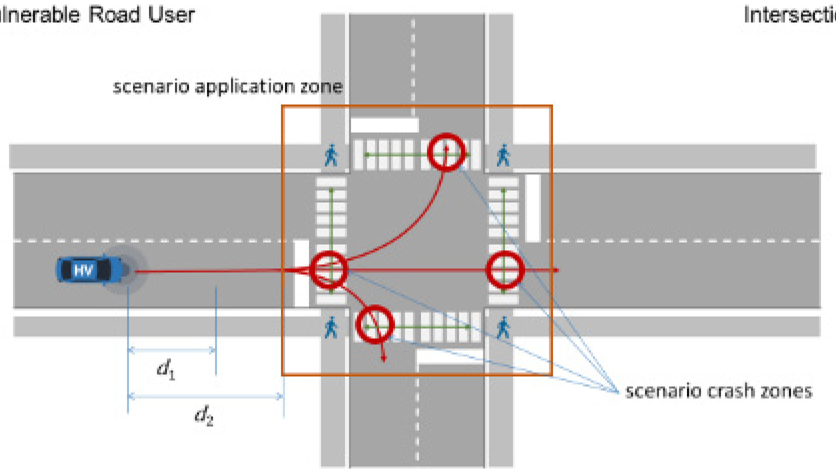
| User Story #1<br>(Lane change warning – lagging vehicle{:RV1_v>HV_v}, High Way) | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 83 | The range is derived from the different between HV (100 km/h) and RV1 (120 km/h) speeds. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | Approx. 300 B per message | Speed, GNSS location, past trajectory, turn sign ON , like BSM frame messaging. |
| **Service Level Latency** | **[ms]** | 400 | Depends on the number of repetitions and message cadence. |
| **Service Level Reliability** | **%** | 99.9 | A Service Level Reliability this high should be enough to allow perceived zero-error appearance of the lane change. False positives are more problematic than false negatives. |
| **Velocity** | **[m/s]** | 33 | Varies between Rural \|Urban \|Highway. But more important for this UC is the speed difference between the HV and RV. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum density in urban scenarios |
| **Positioning Accuracy** | **[m]** | 1.5 | In order to perform lane-accurate positioning, a positioning accuracy of around 1.5 m should be provided. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability between different OEMs is needed.<br>Every vehicle should make its presence known periodically (as a broadcast).<br>Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood. |

| User Story #2<br>(Lane change warning –leading vehicle {: HV_v>RV2_v}, Urban) | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 28 | The range is derived from the different between the HV and RV speeds. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | Approx. 300 B per message | Speed, GNSS location, past trajectory, turn sign ON and side, like BSM frame messaging. |
| **Service Level Latency** | **[ms]** | 400 | Depends on the number of repetitions and message cadence. |
| **Service Level Reliability** | **%** | 99.9 | A service level reliability this high should be enough to allow perceived zero-error appearance of the lane change. False positives are more problematic than false negatives. |
| **Velocity** | **[m/s]** | 14 | Varies between Rural \|Urban \|HW. But more important for this UC is the speed difference between the HV and RV. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum density in urban scenarios. |
| **Positioning Accuracy** | **[m]** | 1.5 | In order to perform lane-accurate positioning, a positioning accuracy of around 1.5 m should be provided. |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability between different OEMs is needed.<br>It should be regulated that every vehicle has to make its presence known periodically (as a broadcast).<br>Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood. |
| **User Story #3<br>(Lane change warning –Not Permitted {: T_Manoeuvre>T_safe}, Rural)** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 51 | The range is derived from the different between the HV and RV speeds, |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | Approx. 300 B per message | Speed, GNSS location, past trajectory, turn sign ON and side, like BSM frame messaging. |
| **Service Level Latency** | **[ms]** | 400 | Depends on the number of repetitions and message cadence. |
| **Service Level Reliability** | **%** | 99.9 | A service level reliability this high should be enough to allow perceived zero-error appearance of the lane change. False positives are more problematic than false negatives. |
| **Velocity** | **[m/s]** | 23 | Varies between Rural \|Urban \|HW. But more important for this UC is the speed difference between the HV and RV. |
| **Vehicle Density** | **[vehicle/km^2]** | 12000 | Maximum density in urban scenarios. |

| | | | |
|---|---|---|---|
| **Positioning Accuracy** | **[m]** | 1.5 | In order to perform lane-accurate positioning, a positioning accuracy of around 1.5 m should be provided. |
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes / Yes / Yes | Interoperability between different OEMs is needed.<br>It should be regulated that every vehicle has to make its presence known periodically (as a broadcast).<br><br>Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood. |

### 6.1.7 Vulnerable Road User

| | |
|---|---|
| **Use Case Name** | Vulnerable Road User |
| **User Story** | Alert HV of approaching VRU in the road or crossing an intersection and warn of any risk of collision |
| **Category** | Safety |
| **Road Environment** | Intersection \| Urban \| Rural \| Highway \| Other |
| **Short Description** | Alert HV of approaching VRU in the road or crossing an intersection and warn of any risk of collision |
| **Actors** | ▸ Vulnerable Road User (VRU)<br>▸ Surveillance cameras at traffic lights/crossings |
| **Vehicle Roles** | ▸ HV represents the vehicle moving forward |
| **Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Intersections are defined by their crossing designations and geometry<br>▸ Traffic lights and stop signs control right of way traffic flow through an intersection (if available)<br>▸ Pedestrian crossings are defined by their designations and geometry |
| **Other Actors' Roles** | VRU represents a pedestrian, bike, eBike, motorbike, skateboard etc. that is travelling along the road or intends to cross the road |
| **Goal** | ▸ Avoid collision between HV and VRU |
| **Needs** | ▸ HV needs to be aware of VRU on the road and any risk of collision<br>▸ HV needs to be aware of VRU at an intersection and any risk of collision |
| **Constraints/ Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's safe stopping distance<br>– VRU's trajectory is constant<br>– extent of scenario application zones |
| **Geographic Scope** | Global |

| | |
|---|---|
| **Illustrations** | Vulnerable Road User In Road<br><br><br>Vulnerable Road User Intersection<br><br><br>▸ $d_1$ = stopping distance of HV<br>▸ $d_2$ = distance from HV to scenario crash zone |
| **Pre-Conditions** | ▸ HV is moving forward<br>▸ Before establishment of LoS, if any<br>▸ Known VRU is characterised (bike, pedestrian, motorcycle,…)<br>▸ The ‘In Road’ scenario application zone is determined from:<br>– HV’s location and dynamics<br>– HV’s safe stopping distance<br>– Lane designations and geometry<br>– Road conditions (if available)<br>▸ The ‘Intersection’ scenario application zone is determined from:<br>– HV’s location and dynamics<br>– HV’s safe stopping distance<br>– Intersection geometry<br>– Road conditions (if available) |

| | |
|---|---|
| **Main Event Flow** | ▸ If VRU is in the 'On Road' scenario application zone:<br>– If HV's trajectory and VRU's trajectory are on a collision course then:<br>– Warn HV of the risk of collision with the approaching VRU<br>– Otherwise:<br>– Caution HV of the approaching VRU |
| **Alternative Event Flow** | ▸ If VRU is in the 'Intersection' scenario application zone;<br>– If HV's trajectory and VRU's trajectory are on a collision course then<br>– Warn HV of the risk of collision with the approaching VRU<br>– Otherwise<br>– Caution HV of the approaching VRU |
| **Post-Conditions** | ▸ HV/Driver is aware of its approach towards the VRU and any risk of collision (Day 1-1.5)<br>▸ HV is aware of its approach towards the VRU and takes the necessary safety measures to avoid or mitigate collision (Day 3) |
| **Service Level Requirements** | ▸ Positioning accuracy<br>▸ Information age<br>▸ Communications range |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's safe stopping distance<br>▸ VRU's location and dynamics<br>▸ VRU's characterisation (bike, pedestrian, motorcycle,…)<br>▸ Lane designations and geometry<br>▸ Intersection geometry<br>▸ Current road conditions (if available)<br>▸ Other vehicle sensor data |

| User Story | Detailed description, specifics and main differences to the User Story in the main template |
|---|---|

| | |
|---|---|
| **User Story #1**<br>**Awareness of the presence of VRUs near potentially dangerous situations** | This VRU User Story describes a scenario in which a presence warning at crossings and spots without line-of-sight (LoS), e.g. automatic detection of pedestrians waiting and/or crossing from infrastructure is intended. VRUs are watched via infrastructure support as surveillance cameras/wireless detection mechanisms and/or are equipped with mobile VRU devices (UE). Awareness notifications are shared with drivers e.g. via roadside units/ monitoring system attached to a 3GPP system (e.g. potentially using MEC) sending messages to drivers or drivers C-ITS systems monitor actively VRUs that are equipped with a device.<br>The User Story involves one or multiple vehicles and it assumes V2I and/or V2P connectivity.<br>In this User Story a vehicle has entered an area in which VRUs are present.<br>▸ The area could be crossings (incl. cross-walks, zebra crossings) and spots without LoS.<br>▸ VRUs are watched via infrastructure support as surveillance cameras/wireless detection mechanisms and/or are equipped with mobile VRU devices (UE).<br>▸ Awareness notifications are shared with drivers, for example via:<br>– Roadside units<br>– Monitoring systems attached to a 3GPP system (extension of User Story, e.g. potentially using MEC) sending messages to drivers or vehicle's C-ITS system, and actively monitoring VRUs that are equipped with a device |
| **User Story #2**<br>**Collision risk warning** | This VRU User Story describes a scenario in which a collision prevention at crossings and spots without LoS, e.g. automatic detection of pedestrians waiting and/or crossing from infrastructure is intended.<br>In this VRU User Story the accuracy, performance and functionality of VRU devices including UEs is sufficient for collision risk detection, and vehicles share the information collected by sensors with each other.<br>Vehicles have entered an area in which VRUs are present.<br>▸ The area could be crossings (incl. cross-walks, zebra crossings) and spots without line-of-sight<br>▸ VRUs are watched via infrastructure support as surveillance cameras/wireless detection mechanisms and/or are equipped with mobile VRU devices (UE)<br>▸ VRUs are watched via information collected by vehicles sensors and relevant information is shared with other vehicles and/or road site units<br>▸ Warning notifications are shared with drivers, for example via:<br>– Roadside units<br>– Monitoring systems attached to a 3GPP system (e.g. potentially using MEC) sending messages to drivers<br>– Other vehicle's C-ITS system based on sensor data<br>– Vehicle's C-ITS systems actively monitoring VRUs that are equipped with a device<br>▸ Cooperative actions and manoeuvres are enabled via cooperative message exchange in a bi-directional manner<br>▸ The system should convey information from a VRU in a power-efficient way. For example, it could be investigated if providing a power saving feature on the sidelink for handheld UEs is a solution. For instance, the eNB-aided form of discontinuous transmission/reception (DTX/DRX) that allows for power-saving in the UE should be considered by 3GPP System. Or perhaps enhancements on application or transport layer etc. are more appropriate.<br>▸ The 3GPP System should provide a network-enabled positioning service including history data of trajectories for VRUs. |

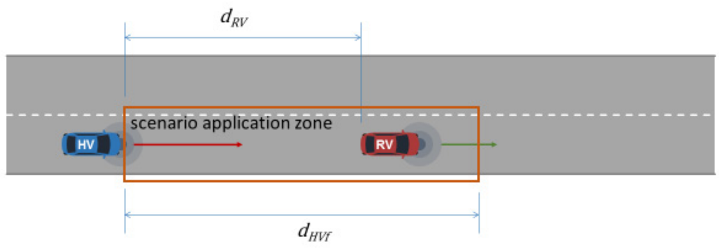
| User Story #1<br>Awareness of the presence of VRUs near potentially dangerous situations | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 300 | For long distances we expect local sensors of the vehicle (electronic horizon) to be able to resolve VRU protection scenarios.<br>We do not foresee that a full stop will be feasible in most VRU protection scenarios. It is rather to trigger an obstacle avoidance manoeuvre. Therefore, 40 m are roughly 2 s driving time when driving with 80 km/h should provide enough time to trigger an appropriate event. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | Initially: 20-40 Mbps to enable raw sensor sharing (e.g. from on-/off-board cameras). Later: around 2 Mbps since only information are shared | Surveillance: The data rate depends strongly on the capabilities of the different C-ITS systems to process received RAW data and generate information data. To allow all 'sensor detected' data being shared we recommended initially a higher data rate. The end goal is to communicate only information/processed data.<br>Safety: Vehicle needs information on the precise location of the VRUs in its vicinity and its own position in the near future.<br>Initially, raw sensor data (e.g. from cameras) is shared, summing up to approx. 20-40 Mbps (H.264 compression assumed), cf. T-190069.<br>Later, assuming 1 kB/VRU/100 ms for information transmission and 25 VRUs, we end up at 2 Mbps. |
| **Service Level Latency** | **[ms]** | 100<br><br>Recommended communication latency: 20 | This is the maximum latency tolerable for a reaction due to moving VRUs very near the road.<br>20 ms for VRU communication latency is comparable to that of cooperative manoeuvres and sensor sharing because we see that the VRU situations will occur much more unexpectedly and in close proximity to the vehicle. Thus, longer communication latencies would be adverse to the intended purpose.<br>Justification: For a 50 km/hr drive in dense urban environments (80 m communication radius), the total time budget until a potential complete stop has to be initiated is approximately 3.96 s. |
| **Service Level Reliability** | **%** | 99.9 | High, the reliability here should be sufficient to guarantee QoS. 99.9 % should be sufficient, since additional vehicle sensors are in place that can help to avoid collisions. |
| **Velocity** | **[m/s]** | 36.11 | Considering 130 km/h max. speed in rural areas |
| **Vehicle Density** | **[vehicle/km^2]** | Concerned VRUs: ~300 total<br>Present VRUs per km^2: ~10,000<br>Vehicles: 12,000 | Figures given only for urban areas, since we consider this as the more critical case with regards to vehicle number/density.<br>VRUs concerned are those near streets, not counting workers in offices or the like. However, for total network load, etc., all VRUs in the given area have to be considered, or as many as the network can support. |

| | | | |
|---|---|---|---|
| **Positioning Accuracy** | **[m]** | 1-2 | In order to correct positioning based on GNSS (e.g. GPS, Galileo), this accuracy should be enhanced via the 3GPP System.<br><br>The 3GPP System provides a positioning accuracy of 1-2 m, e.g. considering support of GNSS, highly accurately positioned RSU and CV2X UEs. |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes | In order to make it possible to share information and data on VRUs between vehicles, inter-OEM-operability should be guaranteed.<br><br>Interoperability of UEs with RSUs, vehicles, and other local entities should also be guaranteed. |
| **User Story #2<br>Collision risk warning** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 300 | Limited range for calculations = 80 m, since this is the communication range in very dense metropolitan areas.<br><br>For longer-distances we expect other local sensors of the vehicle (electronic horizon) to be able to assist in VRU protection scenarios.<br><br>We do not foresee that a full stop will be feasible in most VRU protection scenarios. It is rather to trigger an obstacle avoidance manoeuvre. Therefore, 40 m are roughly 2 s driving time when driving with 80 km/h should provide enough time to trigger an appropriate event. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | Initially: 20-40 Mbps to enable raw sensor sharing (e.g. from on-/off-board cameras). Later: around 2 Mbps since only information are shared. | Surveillance: The data rate depends strongly on the capabilities of the different C-ITS systems to process received RAW data and generate information data. To allow all 'sensor detected' data being shared we recommended initially a higher data rate.<br><br>Safety: Vehicle needs information on the precise location of the VRUs in its vicinity and its own position in the near future.<br><br>Initially, raw sensor data (e.g. from cameras) is shared, summing up to approx. 20-40 Mbps (H.264 compression assumed), cf. T-190069.<br><br>Later, assuming 1 kB/VRU/100 ms for information transmission and 25 VRUs, we end up at 2 Mbps. |
| **Service Level Latency** | **[ms]** | 100<br><br>Recommended communication latency: 20 | This is the maximum latency tolerable for a reaction due to moving VRUs very near the road.<br><br>20 ms for VRU communication latency are comparable to that of cooperative manoeuvres and sensor sharing because we see that the VRU situations will occur much more unexpected and in close proximity to the vehicle. Thus, longer communication latencies would be adverse to the intended purpose.<br><br>Justification: For a 50 km/hr drive in dense urban environments (80 m communication radius), the total time budget until a potential complete stop has to be initiated is approximately 3.96 s. |

| | | | |
|---|---|---|---|
| **Service Level Reliability** | **%** | 99.9 | High, the reliability here should be sufficient to guarantee QoS. Here, 99.9% should be sufficient, since additional vehicle sensors are in place that can help to avoid collisions. |
| **Velocity** | **[m/s]** | 36.11 | Considering 130 km/h max. speed in rural areas. |
| **Vehicle Density** | **[vehicle/km^2]** | Concerned VRUs: ~300 total<br>Present VRUs per km^2: ~10,000<br>Vehicles: 12,000 | Figures given only for urban areas, since we consider this one as the more critical case with regards to vehicle number/density.<br>Concerned VRUs are those near streets, not counting workers in offices or the like. However, for total network load, etc.; all VRUs in the given area have to be considered. |
| **Positioning Accuracy** | **[m]** | < 0.5 | In order to correct positioning based on GNSS (e.g. GPS, Galileo), this accuracy should be enhanced via the 3GPP System.<br>The 3GPP System provides a positioning accuracy of < 0.5 m, e.g. considering support of GNSS, highly accurately positioned RSU and CV2X UEs. |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | In order to make it possible to share information and data on VRUs between vehicles, inter-OEM-operability should be guaranteed. Interoperability of UEs with RSUs, vehicles, and other local entities should also be guaranteed.<br>Sharing information collected by sensor data form vehicles passing/approaching the area where VRUs are present references UC T-170339. |

### 6.1.8 Forward Collision Warning

| | |
|---|---|
| **Use Case Name** | Forward Collision Warning |
| **User Story** | The HV is warned that it is on a trajectory to collide with a lead RV that is stopped or moving at a slower speed |
| **Category** | Safety |
| **Road Environment** | Urban \| Rural \| Highway |
| **Short Description** | ▸ Warns HV if it is on a trajectory to collide with a stopped or slower moving RV |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle (RV) |
| **Vehicle Roles** | ▸ HV represents the faster moving vehicle approaching RV from behind<br>▸ RV represents the stopped or slower moving lead vehicle |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid a rear end collision between HV and RV |
| **Needs** | ▸ HV needs to know if there is a risk of collision with RV |
| **Constraints/ Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's safe following distance |
| **Geographic Scope** | ▸ Global |

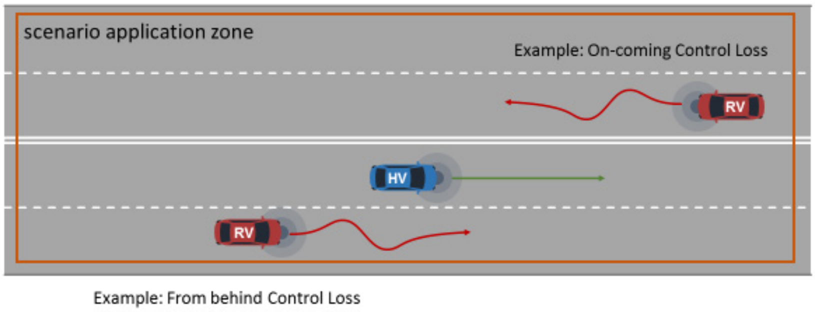
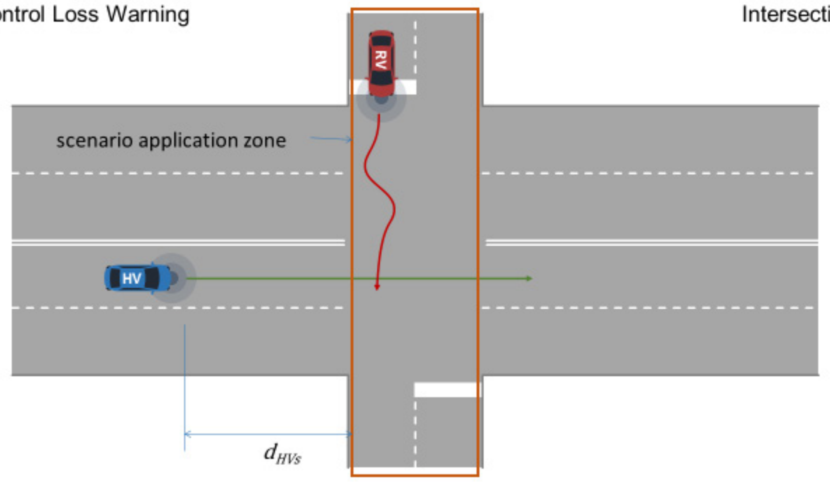
| | |
|---|---|
| **Illustrations** | Forward Collision Warning<br><br><br>▸ $d_{RV}$ = distance between HV and RV<br>▸ $d_{HVf}$ = safe following distance of HV |
| **Pre-Conditions** | ▸ HV is following a slower moving RV<br>▸ The “Forward Collision Warning” scenario application zone is determined from:<br>– HV’s location and dynamics<br>– HV’s safe following distance<br>– Lane designations and geometry<br>– Road Conditions (if available) |
| **Main Event Flow** | ▸ If RV is in “Forward Collision Warning” scenario application zone:<br>– HV is warned of the risk of a rear-end collision with RV |
| **Post-Conditions** | ▸ HV is aware of a risk of collision with RV |
| **Service-Level Key Performance Indicators** | ▸ Positioning Accuracy<br>▸ Information Age<br>▸ Communications Range |
| **Information Requirements** | ▸ HV’s location and dynamics<br>▸ HV’s safe following distance<br>▸ RV’s location and dynamics<br>▸ Lane designations and geometry<br>▸ Current Road Conditions (if available) |

| **User Story #1** | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/ Background** |
| **Range** | **[m]** | 150 | Assuming maximum velocities of 250 km/h on highways requirement for save vehicle distance. |
| **Information Requested/Generated** | **Quality of information/ Information needs** | 300 B | Based on experience from CAM/ BSM. |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.99 | |
| **Velocity** | **[m/s]** | 70 | |

| | | | |
|---|---|---|---|
| **Vehicle Density** | **[vehicle/km^2]** | 12000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

### 6.1.9 Control Lost Warning

| | |
|---|---|
| **Use Case Name** | Control Lost Warning |
| **User Story** | Warn HV of RV that has lost control |
| **Category** | Safety |
| **Road Environment** | Intersection \| Urban \| Rural \| Highway |
| **Short Description** | Warn HV of a nearby RV that has lost control |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle (RV) |
| **Vehicle Roles** | ▸ HV represents the vehicle being alerted<br>▸ RV represents the vehicle that has lost control |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Intersections are defined by their crossing designations and geometry |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid a collision between HV and RV |
| **Needs** | ▸ HV needs to be aware of an RV that has lost control and:<br>– nature of the control loss; breaking, steering, power, etc.<br>– risk of collision |
| **Constraints / Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's safe stopping distance<br>– extent of scenario application zones |
| **Geographic Scope** | Global |

| | |
|---|---|
| **Illustrations** | Control Loss Warning — On Road<br><br><br>Control Loss Warning — Intersection<br><br><br>$d_{HVs}$ = safe stopping distance of HV |
| **Pre-Conditions** | ▸ Known out of control RV is defined by its type and defining parameters<br>▸ The ‘On Road’ scenario application zone is determined from:<br>– HV’s location and dynamics<br>– lane designations and geometry<br>– road conditions (if available)<br>▸ The ‘Intersection’ scenario application zone is determined from:<br>– HV’s location and dynamics<br>– HV’s safe stopping distance<br>– intersection geometry<br>– road conditions (if available) |
| **Main Event Flow** | ▸ If the out of control RV is in the ‘On-Road’ scenario application zone:<br>a. Warn HV of RV, its control loss nature and defining parameters<br>b. If there is a risk of collision based on the estimated trajectories of HV and RV then;<br>i. HV is warned of a risk of collision with RV |

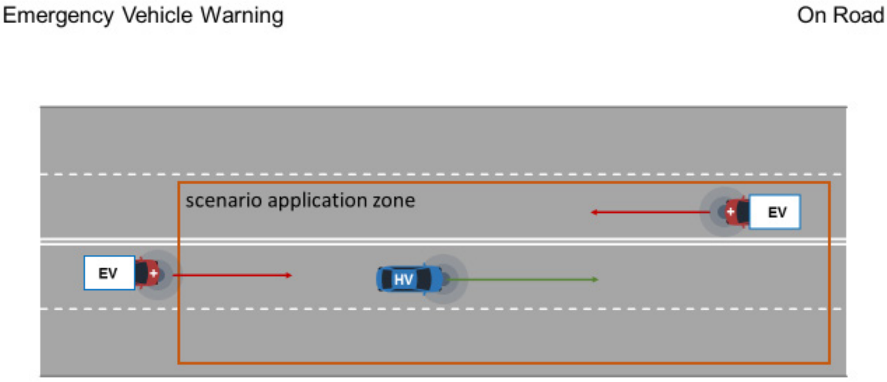
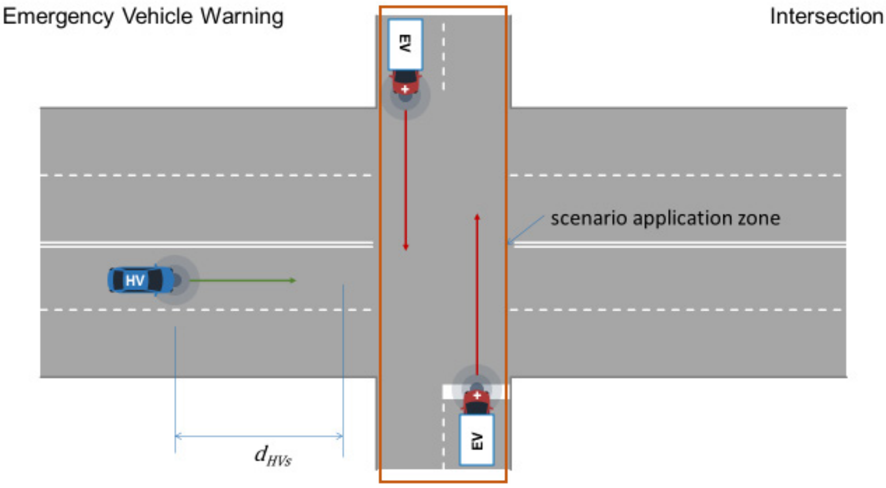
| | |
|---|---|
| **Alternate Event Flow** | ▸ If the out of control RV is in the 'Intersection' scenario application zone:<br>a. Warn HV of RV, its control loss nature and defining parameters<br>b. If there is a risk of collision based on the estimated trajectories of HV and RV then;<br>i. HV is warned of a risk of collision with RV |
| **Post-Conditions** | ▸ HV is aware of the RV that has lost control, its nature and any risk of collision |
| **Service-Level Key Performance Indicators** | ▸ Positioning Accuracy<br>▸ Information Age<br>▸ Communications Range |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's safe stopping distance<br>▸ RV's location and dynamics<br>▸ RV's control loss nature; breaking, steering, power, etc.<br>▸ Lane designations and geometry<br>▸ Intersection geometry<br>▸ Current Road Conditions (if available) |

| User Story | Description |
|---|---|
| **#1: CLW on road** | An oncoming RV gets out of control. |
| **#2: CLW at Intersection** | A RV in an intersection gets out of control. |

| **User Story #1/2** | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 220 | Assuming oncoming traffic with maximum velocities of 100 km/h on highways (resulting in 200 km/h relative speed), reaction time (750 ms) + safe reaction distance (3s): 55 m/s*4 s = 220 m. |
| **Information Requested/Generated** | **Quality of information/ Information needs** | 300 B | Based on experience from CAM/BSM. |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.99 | |
| **Velocity** | **[m/s]** | 70 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3σ) | Lane level accuracy. |
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

### 6.1.10 Emergency Vehicle Warning

| | |
|---|---|
| **Use Case Name** | Emergency Vehicle Warning |
| **User Story** | Alert HV of approaching emergency vehicle |
| **Category** | Safety |
| **Road environment** | Intersection \| Urban \| Rural \| Highway |
| **Short Description** | ▸ Alerts HV of emergency vehicle that is approaching on a trajectory that will cross its paths |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Emergency Vehicle (EV) |
| **Vehicle Roles** | ▸ HV represents the vehicle to yield to the emergency vehicle<br>▸ EV represents the approaching emergency vehicle |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Intersections are defined by their crossing designations and geometry |
| **Other Actors' Roles** | ▸ N/A |
| **Goal** | ▸ Alert HV of the presence, nature and characteristics of an emergency vehicle<br>▸ HV to yield and clear right of way to approaching emergency vehicle |
| **Needs** | ▸ HV needs to know of an approaching EV and:<br>– nature of its operation; fire, police, ambulance…<br>– direction of approach; behind, left, right, on-coming |
| **Constraints/ Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's safe stopping distance<br>– extent of scenario application zones |
| **Geographic Scope** | Global |

| | |
|---|---|
| **Illustrations** | <br><br><br><br>$d_{HVs}$ = safe stopping distance of HV |
| **Pre-Conditions** | ▸ EV is approaching HV<br>▸ EV is defined by its nature<br>▸ The 'On Road' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe stopping distance<br>– lane designations and geometry<br>– road conditions (if available)<br>▸ The 'Intersection' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe stopping distance<br>– intersection geometry<br>– road conditions (if available) |
| **Main Event Flow** | ▸ If EV is in the 'On-Road' scenario application zone:<br>▸ Alert HV of EV, its nature and direction of approach |

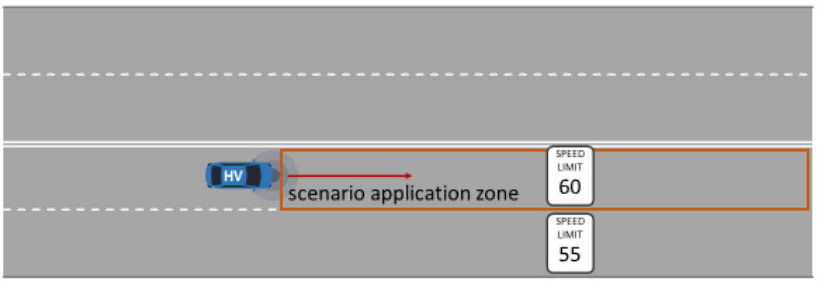
| | |
|---|---|
| **Alternate Event Flow** | ▸ If EV is in the 'Intersection' scenario application zone:<br>– Alert HV of EV, its nature and direction of approach |
| **Post-Conditions** | ▸ HV is aware of the approaching EV, its nature and direction of approach. |
| **Service-Level Key Performance Indicators** | ▸ Positioning accuracy<br>▸ Information age<br>▸ Communications range |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's safe stopping distance<br>▸ EV's location and dynamics<br>▸ EV's nature; ambulance, police, fire,...<br>▸ Lane designations and geometry<br>▸ Intersection geometry<br>▸ Road conditions (if available) |

| User Story | Description |
|---|---|
| **#1: EV on road** | An EV is approaching from behind or on the opposite lane. |
| **#2: EV at Intersection** | An EV is approaching at an intersection. |

| User Story #1/2 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 220 | Assuming oncoming traffic with maximum velocities of 100 km/h on highways (resulting in 200 km/h relative speed), reaction time (750 ms) + safe reaction distance (3 s): 55 m/s*4 s=220 m |
| **Information Requested/Generated** | **Quality of information/ Information needs** | 300 | Similar BSM / DENM or CAM. |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.99 | |
| **Velocity** | **[m/s]** | 70 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

### 6.1.11 Speed Limit Warning

| | |
|---|---|
| **Use Case Name** | Speed Limit Warning |

| | |
|---|---|
| **User Story** | Alert HV when it exceeds the roads posted speed limit |
| **Category** | Safety |
| **Road Environment** | Urban \| Rural \| Highway |
| **Short Description** | HV warns driver if the speed limit is exceeded |
| **Actors** | ▸ Host Vehicle (HV) |
| **Vehicle Roles** | ▸ HV represents the vehicle exceeding the speed limit |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Posted Speed Limits are associated with road and lane segments |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Alert HV of violated speed limit |
| **Needs** | HV need to know if it is violating the road segment's posted speed limit and its nature (maximum or minimum) |
| **Constraints/ Presumptions** | ▸ A speed limit violation assumes:<br>– A defined threshold in excess of the posted speed limit that triggers a violation<br>– A defined period of time that the threshold must be exceeded before triggering the violation alert. |
| **Geographic Scope** | Global |
| **Illustrations** | Speed Limit Warning<br><br> |
| **Pre-Conditions** | ▸ HV is moving forward<br>▸ The scenario application zone is determined from:<br>– HV's location and dynamics<br>– lane designations and geometry<br>▸ The lane or road segments posted speed limit is known. |
| **Main Event Flow** | ▸ If HV's speed exceeds the lane or road segments posted speed limit in the scenario application zone:<br>– Alert HV of the speed limit violation and its nature (maximum or minimum) |

| | |
|---|---|
| **Post-Conditions** | ▸ HV is aware of the speed limit violation |
| **Service-Level Key Performance Indicators** | ▸ Positioning Accuracy<br>▸ Information Age<br>▸ Communications Range |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ Lane designations and geometry<br>▸ Speed limit associated with lane or road segments and its nature (maximum or minimum) |

| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 50 | As the warning is only issued if the vehicle is exceeding the speed limit withing the scenario application zone, even 0m would be sufficient. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B per message | Depending on implementation, needs to convey speed limit and area the speed limit is relevant. |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99 | |
| **Velocity** | **[m/s]** | 70 | Needs to support up to maximum speed on freeways. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum assumed traffic density. |
| **Positioning Accuracy** | **[m]** | 1.5 (3s) | Lane level accuracy as speed limits might apply to single lanes only. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

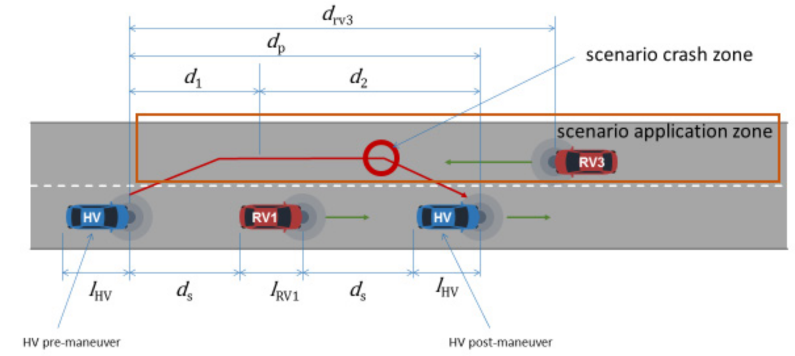
### 6.1.12 Do Not Pass Warning

| | |
|---|---|
| **Use Case Name** | Do Not Pass Warning |
| **User Story** | An HV that signals an intention to pass a vehicle using the oncoming traffic lane is alerted if it is unsafe to do so |
| **Category** | Safety |
| **Road Environment** | Urban \| Rural \| Highway |
| **Short Description** | ▸ Alert HV that is intending to pass RV1 using the oncoming traffic lane that there is an oncoming RV2 within the safe passing distance required to complete the manoeuvre<br>▸ Alert HV that is intending to pass RV1 using the oncoming traffic lane that there is not enough space between RV1 and RV3<br>▸ Alert HV that is intending to pass RV1 using the oncoming traffic lane that passing is not permitted along the current road section |

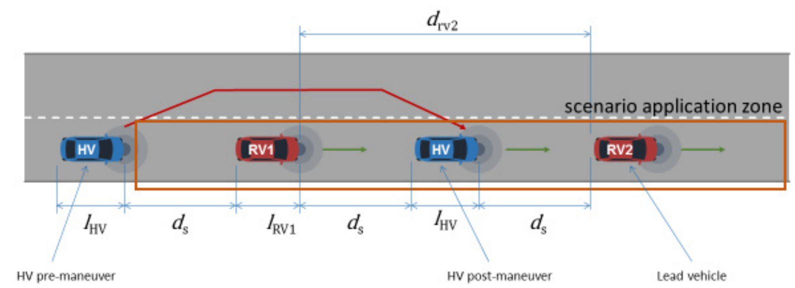
| | |
|---|---|
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle 1 (RV1)<br>▸ Remote Vehicle 2 (RV2)<br>▸ Remote Vehicle 3 (RV3) |
| **Vehicle Roles** | ▸ HV represents the vehicle intending to pass RV1<br>▸ RV1 represents the vehicle being passed<br>▸ RV2 represents the lead vehicle in front of RV1<br>▸ RV3 represents the closest vehicle in the oncoming traffic lane |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Roads lines and signs indicate where passing is not permitted |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid a head on collision between HV and RV3 |
| **Needs** | ▸ HV needs to know if there is enough distance between itself and RV3 to complete the full passing manoeuve<br>▸ HV needs to know if there is enough space between RV1 and RV2 to safely return to the driving lane after completing the passing manoeuvre<br>▸ HV needs to know if passing is permitted on the current stretch of road |
| **Constraints / Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's pre-manoeuvre safe following distance<br>– HV's post-manoeuvre safe following distance<br>– HV's incremental passing velocity<br>– HV's estimated acceleration to reach the passing velocity<br>– RV1's safe following distance |
| **Geographic Scope** | Global |

**Illustrations**

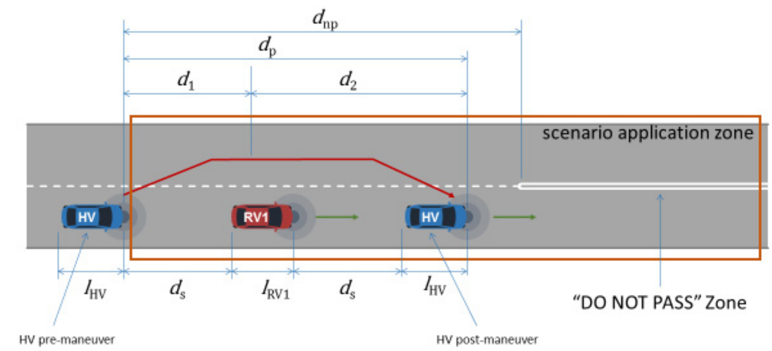
Do Not Pass Warning On-coming Vehicle




Do Not Pass Warning Lead Vehicle




Do Not Pass Warning Not Permitted




- $d_{rv2}$ = absolute distance between RV1V and RV2
- $d_{rv3}$ = absolute distance between HV and RV3
- $d_{np}$ = absolute distance between HV and "DO NOT PASS"zone
- $d_p$ = relative distance required for HV to overtake RV1
- $d_1$ = relative distance for HV to accelerate to passing velocity
- $d_2$ = relative distance travelled by HV at passing velocity
- $l_{HV}$ = lenght of HV
- $l_{RV1}$ = lenght of RV1
- $d_s$ = safe following distance

| | |
|---|---|
| **Pre-Conditions** | ▸ HV is following a slower moving RV1<br>▸ HV signals intention to move into oncoming traffic lane<br>▸ Known 'DO NOT PASS' road segments are defined by their begin and end locations<br>▸ The 'On-coming Vehicle' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe following distance<br>– HV's length<br>– HV's incremental passing velocity<br>– HV's estimated acceleration to reach the passing velocity<br>– RV1's location and dynamics<br>– RV1's safe following distance<br>– RV1's length<br>– Lane designations and geometry<br>– Posted speed limits<br>– Road Conditions (if available)<br>▸ The 'Lead Vehicle' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe following distance<br>– HV's length<br>– RV1's location and dynamics<br>– RV1's safe following distance<br>– RV1's length<br>– Lane designations and geometry<br>– Posted speed limits<br>– Road Conditions (if available)<br>▸ The 'Not Permitted' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe following distance<br>– HV's length<br>– HV's incremental passing velocity<br>– HV's estimated acceleration to reach the passing velocity<br>– RV1's location and dynamics<br>– RV1's safe following distance<br>– RV1's length<br>– Lane designations and geometry<br>– Posted speed limits<br>– Road Conditions (if available) |

| | |
|---|---|
| **Main Event Flow** | ▸ If RV3 is in the 'On-Coming Vehicle' scenario application zone;<br>– The distance required to safely complete the passing manoeuvre is determined using:<br>– HV's location and dynamics<br>– HV's safe following distance<br>– HV's length<br>– HV's incremental passing velocity<br>– HV's estimated acceleration to reach the passing velocity<br>– RV1's location and dynamics<br>– RV1's safe following distance<br>– RV1's length<br>– The distance available to complete the passing manoeuvre is determined using:<br>– HV's location and dynamics<br>– RV3's location and dynamics<br>– The required passing distance is compared with the available passing distance and HV is warned not to pass if there is a risk of a head-on collision with RV3 |
| **Alternative Event Flow** | ▸ If RV2 is in the 'Lead Vehicle' scenario application zone;<br>– The space between RV1 and RV2 required to safely return to the passing lane is determined using:<br>– HV's location and dynamics<br>– HV's pre-manoeuvre safe following distance<br>– HV's post-manoeuvre safe following distance<br>– HV's length<br>– RV1's location and dynamics<br>– RV1's safe following distance<br>– RV1's length<br>– The space between RV1 and RV2 available to safely return to the passing lane is determined using:<br>– RV1's location and dynamics<br>– RV2's location and dynamics<br>– The required space is compared with the available space and HV is warned not to pass if there is not enough space to safely return to the driving lane |
| **Alternative Event Flow** | ▸ If a 'DO NOT PASS' road segment is in the 'Not Permitted' scenario application zone;<br>– HV is warned of the violation risk |
| **Post-Conditions** | ▸ HV is aware that it is not safe to pass because of:<br>– risk of a head-on collision with RV3<br>– lead vehicle in front of RV1<br>– Do Not Pass road designation or sign |

| | |
|---|---|
| **Service-Level Key Performance Indicators** | ▸ Positioning Accuracy<br>▸ Communications Range<br>▸ Information Age |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's pre-manoeuvre safe following distance<br>▸ HV's post-manoeuvre safe following distance<br>▸ HV's length<br>▸ HV's incremental passing velocity<br>▸ HV's estimated acceleration to reach the passing velocity<br>▸ RV1's location and dynamics<br>▸ RV1's safe following distance<br>▸ RV1's length<br>▸ RV2's location and dynamics<br>▸ RV3's location and dynamics<br>▸ Posted speed limit<br>▸ 'DO NOT PASS' road segments' begin and end locations Solid road lines and signs are typically used to indicate that passing is not permitted. They are often found on curved roads or approaching intersections<br>▸ Lane designations and geometry<br>▸ Current road conditions (if available) |

| User Story #1/2/3 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 1100 | Maximum assumed velocity: 100 km/h (200 km/h relative – 56 m/s). Minimum speed difference between overtaking vehicles 10 km/h (2.8 m/s). Maximum length of vehicle to overtake 38 m. Estimated length of overtaking vehicle 6 m. Minimum time for overtaking (2*6+38/2.8 s)=~14 s. Travelled distance in 18 s at 56 m/s = 1008 . Required range 1008 + some reaction time. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B per message | Similar to BSM/CAM. |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.99 | |
| **Velocity** | **[m/s]** | 70 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |

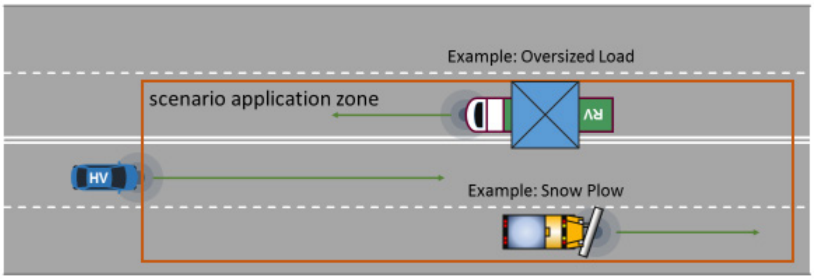
| | | | |
|---|---|---|---|
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

### 6.1.14 Abnormal Vehicle Warning

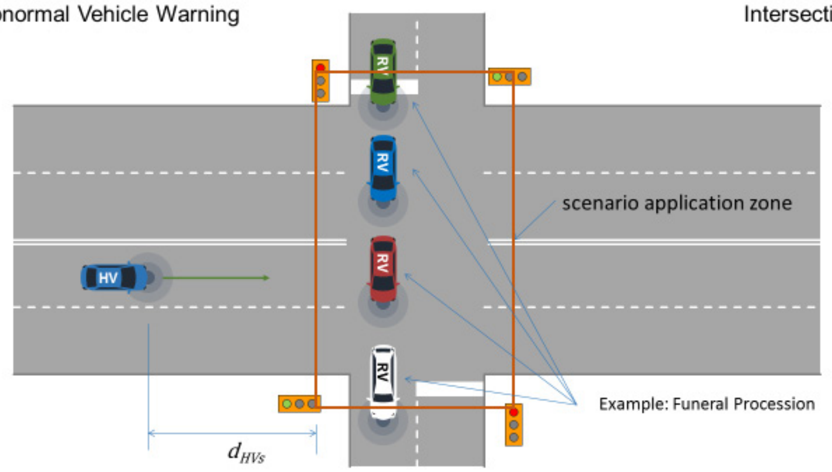
| | |
|---|---|
| **Use Case Name** | Abnormal Vehicle Warning |
| **User Story** | Warn HV of RV that is operating outside of normal parameters such as size, speed, traffic signal and sign compliance |
| **Category** | Safety |
| **Road environment** | Intersection \| Urban \| Rural \| Highway |
| **Short Description** | ▸ Warn HV driver of a nearby RV that is operating outside of normal parameters |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle (RV) |
| **Vehicle Roles** | ▸ HV represents the vehicle being alerted<br>▸ RV represents the vehicle that is operating abnormally |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Intersections are defined by their crossing designations and geometry |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Alert HV of the presence, nature and characteristics of an abnormal RV |
| **Needs** | ▸ HV needs to know if it is approaching an abnormal RV and;<br>– the nature of its operation; oversized load, slow moving vehicle, funeral procession, snow plow, etc.<br>– its defining parameters; location, dynamics, size, traffic signal compliance, … |
| **Constraints/ Presumptions** | ▸ Assumptions will be required for the following information:<br>– HV's safe stopping distance<br>– extent of scenario application zones |
| **Geographic Scope** | Global |

**Illustrations**

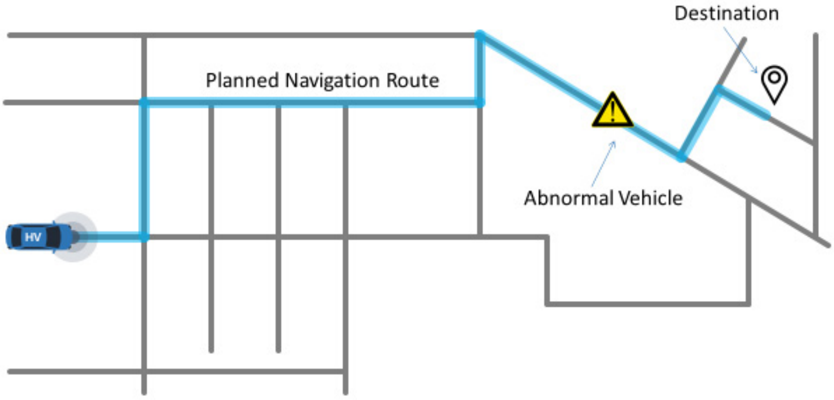
Abnormal Vehicle Warning On Road




Abnormal Vehicle Warning Intersection




Abnormal Vehicle Warning Navigation Route




$d_{HVs}$ = safe stopping distance of HV

| | |
|---|---|
| **Pre-Conditions** | ▸ HV is approaching abnormal RV<br>▸ Known abnormal RV is defined by its nature and defining parameters<br>▸ The 'On Road' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe stopping distance<br>– Lane designations and geometry<br>– Road conditions (if available)<br>▸ The 'Intersection' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe stopping distance<br>– Intersection geometry<br>– Road conditions (if available)<br>▸ The 'Navigation Route' scenario application zone is determined from:<br>– HV's location<br>– HV's planned navigation route |
| **Main Event Flow** | ▸ If the abnormal RV is in the 'On-Road' scenario application zone;<br>a. Warn HV of the abnormal RV, its nature and defining parameters |
| **Alternate Event Flow** | ▸ If the abnormal RV is in the 'Intersection' scenario application zone;<br>a. Warn HV of the abnormal RV, its nature and defining parameters |
| **Alternate Event Flow** | ▸ If the abnormal RV is in the 'Navigation Route' scenario application zone;<br>a. Warn HV of the abnormal RV, its nature and defining parameters |
| **Post-Conditions** | ▸ HV is aware of the abnormal RV its nature and defining parameters |
| **Service-Level Key Performance Indicators** | ▸ Communications Range<br>▸ Positioning Accuracy<br>▸ Data rate<br>▸ Download size<br>▸ Latency<br>▸ Data validity |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's safe stopping distance<br>▸ HV's planned navigation route (if available)<br>▸ Abnormal RV's nature; oversized load, slow moving vehicle, funeral procession, snow plow, etc.<br>▸ Abnormal RV's defining parameters; location, dynamics, size, traffic signal compliance, …<br>▸ Lane designations and geometry<br>▸ Intersection geometry<br>▸ road conditions (if available) |

| User Story | Description |
|---|---|

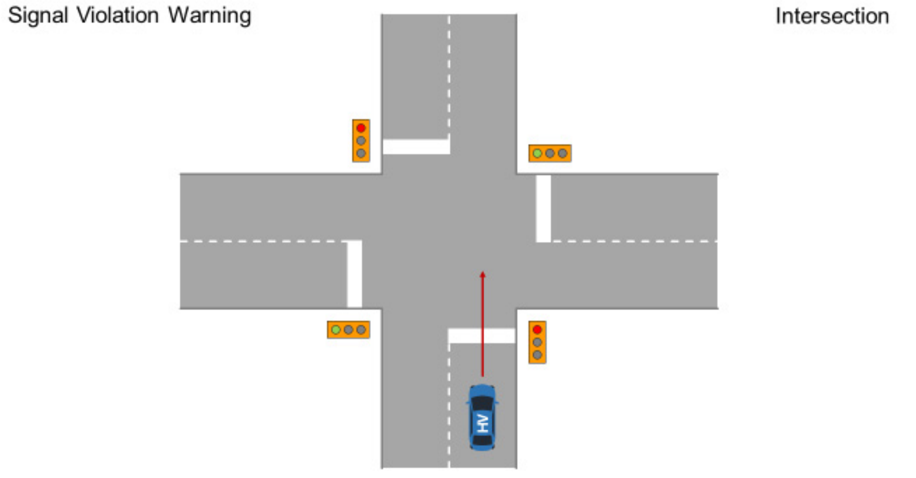
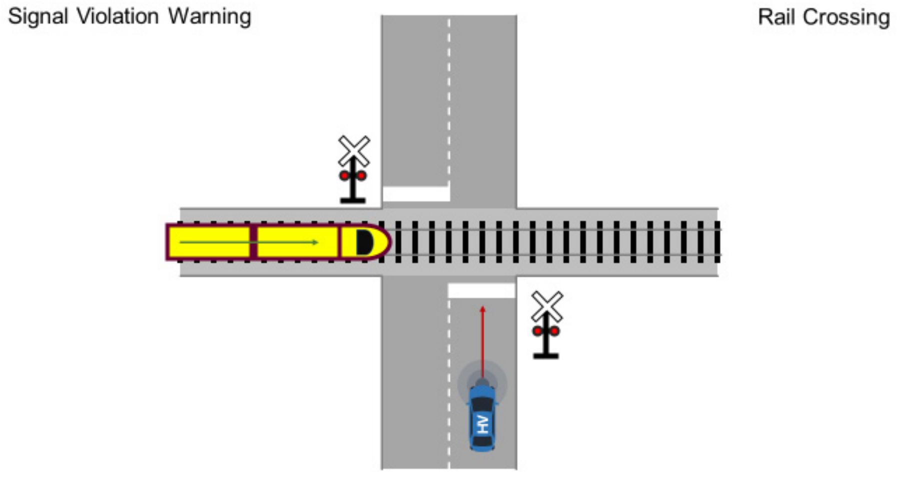
| | |
|---|---|
| **#1: Abnormal vehicle on road** | Abnormal is approaching in opposite direction. |
| **#2: Abnormal vehicle at intersection** | Abnormal vehicles is approaching at an intersection, e.g. as cross-traffic. |
| **#3: Abnormal vehicle on route** | Abnormal vehicle is on navigation route. |

| **User Story #1/2** | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 220 | Assuming oncoming traffic with maximum velocities of 100 km/h on highways (resulting in 200 km/h relative speed), reaction time (750 ms) + safe reaction distance (3 s): 55 m/s*4 s=220 m |
| **Information Requested/Generated** | **Quality of information/ Information needs** | 300 | Similar BSM / DENM or CAM. |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.99 | |
| **Velocity** | **[m/s]** | 70 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |
| **User Story #/3** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 30,000 | Warn early enough to allow for appropriate reaction of driver when approaching the abnormal vehicle.<br>Provide information in time for the navigation system to allow for potential re-routing. |
| **Information Requested/Generated** | **Quality of information/ Information needs** | 300 B per message | Could be similar to BSM/CAM/DENM. |
| **Service Level Latency** | **[ms]** | Minutes | |
| **Service Level Reliability** | | 99% | |
| **Velocity** | **[m/s]** | 70 | Freeways with up to 250 km/h. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |

| | | | |
|---|---|---|---|
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

### 6.1.15 Signal Violation Warning

| | |
|---|---|
| **Use Case Name** | Signal Violation Warning |
| **User Story** | Alert HV that it is at risk of violating an approaching traffic signal |
| **Category** | Safety |
| **Road Environment** | Intersection \| Urban \| Rural |
| **Short Description** | Alerts HV that is at risk of violating an approaching traffic signal |
| **Actors** | ▸ Host Vehicle (HV) |
| **Vehicle Roles** | ▸ HV represents the vehicle approaching a traffic signal |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Intersections are defined by their crossing designations and geometry<br>▸ Traffic lights control right of way traffic flow through an intersection<br>▸ Traffic signal controls right of way at rail crossings |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Avoid a traffic signal violation by HV<br>▸ Avoid a lateral collision between HV and right of way vehicles at an intersection<br>▸ Avoid a lateral collision between HV and train at rail crossing |
| **Needs** | HV needs to know if it is at risk of violating a traffic signal |
| **Constraints/ Presumptions** | N/A |
| **Geographic Scope** | Global |

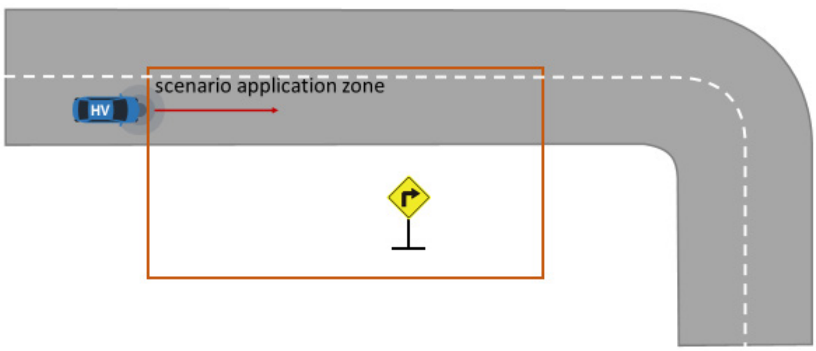
| | |
|---|---|
| **Illustrations** | <br><br><br> |
| **Pre-Conditions** | ▸ HV is moving forward toward intersection or rail crossing<br>▸ The intersections timing and phase is known |
| **Main Event Flow** | ▸ HV's trajectory through the intersection is estimated using;<br>– HV's location & dynamics<br>– Lane designations and geometry<br>– Intersection geometry<br>▸ If HV's trajectory intersects the intersection when the signal phase and timing commands a full stop:<br>– Alert HV of the risk of violating the traffic signal.<br>▸ The intersection can both include regular and alternate intersections such as signalled rail crossings |
| **Post-Conditions** | ▸ HV is aware of the traffic signal and the risk of violation |
| **Service-Level Key Performance Indicators** | ▸ Positioning Accuracy<br>▸ Information Age<br>▸ Communications Range |

| | |
|---|---|
| **Information Requirements** | ▸ Signal Phase and Timing<br>▸ Intersection Geometry<br>▸ Lane designations and geometry<br>▸ Current Road Condition (if available) |

| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/ Background** |
| **Range** | **[m]** | 50 | Breaking distance at 100 km/h. |
| **Information Requested/Generated** | **Quality of information/ Information needs** | | SPAT/MAP |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.99 | |
| **Velocity** | **[m/s]** | 28 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

### 6.1.16 Traffic Sign In Car

| | |
|---|---|
| **Use Case Name** | Traffic Sign in Car |
| **User Story** | Inform HV of the content of an approaching traffic sign; this can be any traffic sign |
| **Category** | Safety |
| **Road environment** | Intersection \| Urban \| Rural \| Highway \| Parking Lots |
| **Short Description** | Informs HV of content of approaching or nearby traffic signs |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Traffic Sign |
| **Vehicle Roles** | ▸ HV represents the vehicle receiving information |
| **Road and Roadside Infrastructure Roles** | ▸ Traffic signs provide laws, guidelines and timely information |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Inform HV of contents of approaching traffic signs |
| **Needs** | HV needs to know the location and content of a traffic sign |
| **Constraints/ Presumptions** | N/A |
| **Geographic Scope** | Global |

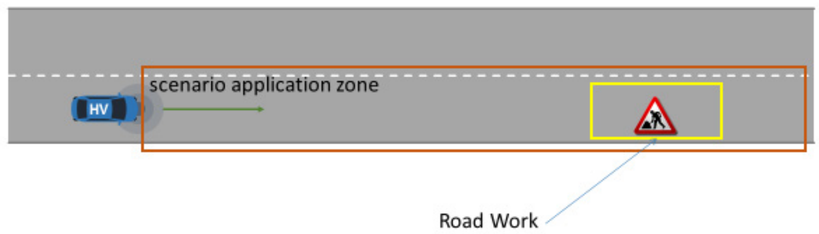
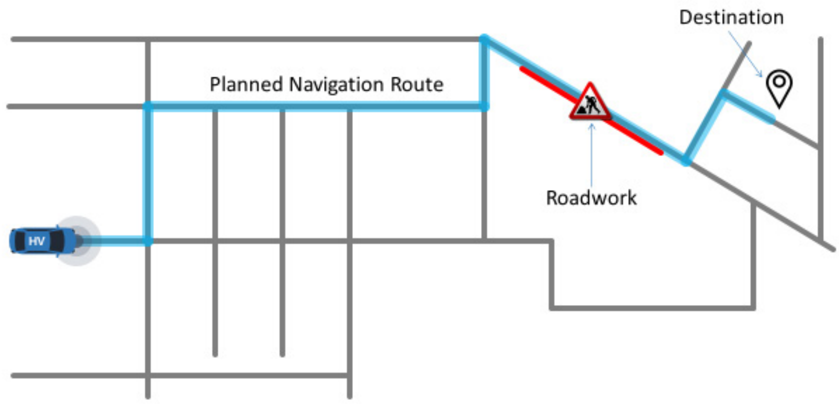
| | |
|---|---|
| **Illustrations** | Traffic Sign In Car<br><br> |
| **Pre-Conditions** | ▸ HV is moving forward<br>▸ Known traffic signs are defined by their location and contents<br>▸ The scenario application zone is determined from:<br>– HV's location and dynamics<br>– lane designations and geometry |
| **Main Event Flow** | ▸ If traffic sign is in the scenario application zone:<br>– Notify HV of the Traffic Sign's location and content |
| **Post-Conditions** | ▸ HV is aware of the traffic sign's location and contents |
| **Service-Level Key Performance Indicators** | ▸ Positioning Accuracy<br>▸ Communications Range |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ Lane designations and geometry<br>▸ Traffic sign location and content |

| **User Story #1** | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 50 | Breaking distance at 100 km/h. |
| **Information Requested/Generated** | **Quality of information/ Information needs** | 300 B | E.g. IVI Message |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.99 | |
| **Velocity** | **[m/s]** | 28 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |

| | | | |
|---|---|---|---|
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes/Yes/ Yes | |

### 6.1.17 Road Work Warning

| | |
|---|---|
| **Use Case Name** | Roadwork Warning |
| **User Story** | Warn HV of approaching roadwork |
| **Category** | Safety |
| **Road Environment** | Intersection \| Urban \| Rural \| Highway |
| **Short Description** | ▸ Warn HV of an approaching roadwork<br>▸ Notify HV of roadwork on the navigation route |
| **Actors** | ▸ Host Vehicle (HV) |
| **Vehicle Roles** | ▸ HV is the vehicle approaching the roadwork |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations, geometry and condition |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Warn HV of approaching roadwork |
| **Needs** | HV needs to know the location, geometry and type of roadwork |
| **Constraints/ Presumptions** | N/A |
| **Geographic Scope** | Global |

| | |
|---|---|
| **Illustrations** | Road Work Warning On Road<br><br><br>Roadwork Warning On Route<br><br> |
| **Pre-Conditions** | ▸ HV is moving forward<br>▸ Known roadwork is defined by its location and geometry<br>▸ The 'On Road' scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe stopping distance<br>– lane designations and geometry<br>– road conditions (if available)<br>▸ The 'On Route' scenario application zone is determined from:<br>– HV's location<br>– HV's planned navigation route |
| **Main Event Flow** | ▸ If the roadwork's location is in the 'On Road' scenario application zone:<br>– Warn HV of the approaching roadwork |
| **Alternative Event Flow** | ▸ If the roadwork's location is in the 'On Route' scenario application zone:<br>– Notify HV of the roadwork's location and geometry<br>– If the roadwork's location is in the 'On Route' scenario application zone: |

| | |
|---|---|
| **Post-Conditions** | ▸ HV is aware of the approaching roadwork<br>▸ HV is aware of the roadwork's location and geometry on the navigation route |
| **Service-Level Key Performance Indicators** | ▸ Communications Range |
| **Information Requirements** | ▸ HV's location and dynamics<br>▸ HV's safe stopping distance<br>▸ HV's planned navigation route (if available).<br>▸ Lane designations and geometry<br>▸ Roadwork's location and geometry |

| User Story | Description |
|---|---|
| **#1: RWW on road** | RW is ahead on the road. HV is approaching RW. |
| **#2: RWW on route** | RW is on planned navigation route. HV could avoid RW by re-routing. |

| **User Story #1** | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/ Reasoning/ Background** |
| **Range** | **[m]** | 300 | Warn early enough to safely brake when approaching the RW. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300 B | E.g. DENM |
| **Service Level Latency** | **[ms]** | 100 | |
| **Service Level Reliability** | **%** | 99.9 | |
| **Velocity** | **[m/s]** | 70 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |
| **User Story #2** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/ Background** |
| **Range** | **[m]** | 30,000 | Situations are relevant along a navigation route or along a road if a navigation route is not known. Depends on the needs for efficient re-routing. |

| | | | |
|---|---|---|---|
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 300-1000 B | |
| **Service Level Latency** | **[ms]** | 1000-5000 | |
| **Service Level Reliability** | **%** | 99 | |
| **Velocity** | **[m/s]** | 70 | |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Assume maximum density in city. |
| **Positioning Accuracy** | **[m]** | 1.5 (3□) | Lane level accuracy. |
| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | |

## 6.2 Vehicle Operations Management

### 6.2.1 Software Update

| | |
|---|---|
| **Use Case Name** | Software Update |
| **User Story** | Vehicle manufacturer updates electronic control module software for targeted vehicles |
| **Category** | Vehicle Operations Management |
| **Road Environment** | Intersection \| Urban \| Rural \| Highway \| Other |
| **Short Description** | ▸ Vehicle Manufacturer or Controlling Authority publishes software updates for one or more ECUs on targeted HVs |
| **Actors** | ▸ Host vehicle (HV)<br>▸ Vehicle manufacturer<br>▸ Controlling authority (could be fleet operator, owner / user onboard, etc.)<br>▸ Human driver |
| **Vehicle Roles** | ▸ HV represents the targeted vehicle for an intended software update |
| **Roadside Infrastructure Roles** | N/A |
| **Other Actors' Roles** | ▸ Vehicle manufacturer publishes software updates<br>▸ Vehicle controlling authority publishes software updates or approves installation of software update |
| **Goal** | Deliver software updates to targeted vehicles |

| | |
|---|---|
| **Needs** | ▸ Vehicle manufacturer needs to distribute software updates<br>▸ Vehicle manufacturer needs to notify HV in case of urgently-needed update<br>▸ Vehicle manufacturer needs to ensure secure delivery of authentic software updates to HV<br>▸ HV needs to download and install software updates<br>▸ HV owner may need to accept or approve application of software updates<br>▸ HV owner needs to accept or reject free optional software updates<br>▸ HV owner needs to purchase or reject optional software updates with new features |
| **Constraints/ Presumptions** | ▸ Vehicle manufacturer targets an update for a list of vehicles<br>▸ A software update may depend on minimum ECU hardware versions, other ECU software versions, or on a chain of previous software versions<br>▸ Scenarios may differ between conventional and autonomous cars<br>▸ HV includes capabilities to download, store, manage, and install software; in many cases a device (or devices) may provide these capabilities for a group of ECUs, while other ECUs may provide these capabilities for themselves<br>▸ A coordinated software update may involve a group of ECUs<br>▸ A software update may be routine (non-urgent) or urgent<br>▸ A software update may be mandatory or optional<br>▸ Software updates may vary in size, depending on target ECU(s); sizes from less than 1 MB to more than 32 GB must be considered<br>▸ Software download must be secure, and the integrity of the downloaded update must be assured (e.g. image signing, etc.)<br>▸ A software update might be rolled back<br>▸ Where feasible, HVs will retain one previous software version to facilitate rollbacks; if this is not feasible, any single SW update package and process should include the capability to roll back the updates contained in that package in case the planned update cannot complete<br>▸ There might need to be multiple, staged updates to move the vehicle systems to the current, recommended or required versions. For example, the steps might include: ECU1 updated from v2.1 to v2.4, then updated from v2.4 to v3.1. ECU2 updated from v5.0 to v6.0 to v7.0 to v7.1. This can be done in one update sequence, but could increase update package size and would affect update timing<br>▸ It may be possible that intermediate update stages (e.g. ECU1 at v2.4 and ECU2 at v6.0) may not be considered compatible or safe, so the entire update sequence may need to be completed before the function or vehicle can be used<br>▸ Downloading software updates must not adversely affect the performance of safety features |
| **Geographic Scope** | Global |
| **Illustrations** | N/A |
| **Pre-Conditions** | ▸ Vehicle manufacturer or controlling authority publishes a software update for a target list of HVs |

| Main Event Flow | |
|---|---|
| **Main Event Flow** | ▸ Vehicle manufacturer or controlling authority posts a mandatory software update and notifies targeted HVs of the new software version on affected ECUs<br>▸ Update can be characterised as routine (non-urgent) or urgent and could target conventional (human-driven) or autonomous (self-driving) vehicles<br>▸ In case of 'Urgent' updates, an 'Urgent Update Required' message is sent to the vehicle, and handled as in the User Stories below<br>▸ HV receives notification and starts downloading the software update<br>▸ HV may download segments of the software update at opportune moments that do not affect the performance of safety features or other driver-facing features such as voice calls or streaming content, or to accommodate changing network availability<br>▸ HV may pause and continue downloads as needed; it should not re-start a large download from the beginning and may receive parts of the download out of order. Thus the download is 'reliable' even given any gaps in coverage or delays caused by higher-priority uses of available bandwidth, or switching between multiple communications mechanisms<br>▸ When HV completes downloading the posted software update:<br>a. HV should either retain a copy of the previously-installed version of software in case of an issue with the update that requires reverting to the previous version or having a mechanism to reverse the changes contained in the SW update package<br>b. HV receives approval from human driver (conventional, if required) or controlling authority (autonomous) to install the software update. Such a separate step after package download is not always mandatory<br>c. HV installs the downloaded software update at a safe, appropriate, driver-approved (where required) time<br>d. HV notifies vehicle manufacturer and controlling authority of update completion and an updated manifest of ECUs, installed software versions, retained rollback versions, any relevant download rate and installation statistics, etc. as appropriate for the SW update process |

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| **Alternative Event Flow** | ▸ Vehicle manufacturer posts an optional software update and notifies targeted HVs of the new software version and features on affected ECUs<br>▸ HV owner is notified of the optional software update, its new features and cost if applicable<br>▸ If HV owner accepts or purchases the update:<br>a. HV starts downloading the software update<br>b. HV may download segments of the software update at opportune moments that do not affect the performance of safety features or other driver-facing features such as voice calls or streaming content<br>c. HV may pause and continue downloads as needed; it should not re-start a large download from the beginning and may receive parts of the download out of order. Thus the download is 'reliable' even given any gaps in coverage or delays caused by higher-priority uses of available bandwidth, or switching between multiple communications mechanisms<br>d. When HV completes downloading the posted software update:<br>i. HV should either retain a copy of the previously-installed version of software in case of an issue with the update that requires reverting to the previous version, or else have a mechanism to reverse the changes contained in the new SW update package<br>ii. HV installs the downloaded software update at a safe, appropriate, driver-approved (where required) time<br>▸ HV notifies vehicle manufacturer and controlling party of update completion and an updated manifest of ECUs, installed software versions, retained rollback versions, any relevant download rate and installation statistics, etc. as appropriate for the SW update process |
| **Post-Conditions** | ▸ Mandatory software updates are deployed on target HVs<br>▸ Optional software updates are either rejected or deployed on target HVs |
| **Service-Level KPIs** | ▸ Download time<br>▸ Download size<br>▸ Reliability |
| **Information Requirements** | ▸ Urgency/criticality of update<br>▸ HV's list of ECUs with current software versions<br>▸ Vehicle manufacturers latest software versions per ECU on each HV<br>▸ Any dependencies between ECUs and software versions<br>▸ HV's software update download progress<br>▸ HV's software update installation progress |

| User Story | Detailed Description and Specifics |
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| **User Story #1**<br>**Software Update (Conventional-Routine)** | The 'normal' case requiring a software update in a conventional (non-autonomous) vehicle. Software download and software installation are separate.<br><br>The software is downloaded securely and reliably, as coverage and bandwidth are available. Its transmission must not adversely affect any safety-critical or user experience-critical functions.<br><br>The driver is asked for consent to install the software when appropriate.<br><br>Software installation is a separate process that occurs when safe and convenient. It may also vary depending on the vehicle manufacturer, model, and specific ECUs. For example, a non-critical system might be updated any time but a safety-critical system might only be updated when the vehicle is securely parked and will not be used for an extended period. |
| **User Story #2**<br>**Software Update (Conventional-Urgent)** | Urgent need for software update in a conventional (human-driven) vehicle.<br><br>Driver is alerted to the need for an update. This could be similar to a 'check engine' light or other alert. Unless otherwise mandated, the SW is downloaded automatically by the vehicle. Where required, the driver is asked for consent to install the software as soon as safe and appropriate. If consent is not required, the vehicle may choose to perform the installation when appropriate, and the driver may be notified before, during, and/or after.<br><br>The software is downloaded securely and reliably, as coverage and bandwidth are available. Its transmission should not interrupt any safety-critical functions.<br><br>Where required, the driver is asked for consent to install the software when appropriate.<br><br>Software installation proceeds as in the case above. |
| **User Story #3**<br>**Software Update (Autonomous-Routine)** | The 'normal' case requiring a software update in an autonomous (self-driving) vehicle.<br><br>The controlling party is asked for consent to install the software, potentially specifying preconditions (e.g. no passengers aboard, during off-peak hours, during next refuelling/recharging, etc.).<br><br>The software is downloaded securely and reliably, as coverage and bandwidth are available. Its transmission must not adversely affect any safety-critical or user experience-critical functions.<br><br>Software installation is a separate process that occurs when safe and the controlling party conditions are met. |

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| **User Story #4**<br><br>**Software Update (Autonomous-Urgent)** | Urgent need for critical software update in an autonomous (self-driving) vehicle. In this case, the first priority may be to order the vehicle to safely exit the roadway and park.<br><br>The controlling party is informed of a critical need for an update and agrees to the vehicle state requirements to perform the download and update (e.g. on route or stopped, passengers on-board or empty, etc.). With controlling party's consent regarding the conditions, the vehicle update is performed, which may require steps to stop in a safe location and inform passengers on-board. Once the controlling party agrees to the conditions, the updates are downloaded to target vehicles, while necessary requirements for update installation (like safely parking) are addressed in parallel.<br><br>If passengers are aboard, the controlling party (e.g. fleet operator) or vehicle informs passengers of the situation and attends to their comfort and safety. For example, another vehicle may be dispatched to carry the passengers to their destinations.<br><br>Assuming no passengers are aboard or the download and installation can be completed with high confidence quickly (within minutes), the software download and installation proceed as in the routine case, but with a higher delivery priority (i.e. streaming or other content downloads take lower priority).<br><br>In cases of longer update installation durations, passengers may be transferred to another vehicle and the download will occur as if routine while the vehicle is parked. However, the high cost of an expensive autonomous vehicle sitting idle while another is needed to deal with passengers, or any time the update can be accomplished more quickly than the arrival of a replacement vehicle, make the 'update while you wait' scenario more compelling. |
| **User Story #5**<br><br>**Software Update (Without Infrastructure)** | Software update delivery outside network service provider coverage. A vehicle is outside of V2I/V2N coverage and enters the C-V2X range of another vehicle with the appropriate software update available.<br><br>For example, two or more similar vehicles from the same managed fleet arrive in close proximity to transfer cargo, refuel/recharge, or for the explicit purpose of receiving an update or other maintenance.<br><br>▸ Assumes a site outside network service or roadside infrastructure coverage where at least two vehicles come into close proximity of each other.<br>▸ At least one vehicle (the 'serving vehicle') holds the appropriate software update and can serve as a secure download server to the target vehicle(s).<br>▸ Before the software transfer is initiated, the system in the serving vehicle identifies the target vehicle(s) and the need for software updates. This process may be done through a bulletin published by the serving vehicle which identifies vehicles needing specific updates.<br>▸ The driver (human or robot) is informed that a critical update is in progress and that the vehicle should not be powered down or driven until update completion.<br><br>The download must happen over a short period while the vehicles are in close proximity of each other. |

| User Story #6<br><br>Software Update (Vehicle to Workshop) | Software update delivery in a specific context, such as a dealership, workshop, or fleet parking facility. A vehicle enters an area where 'private' C-V2X capability/RSU can quickly deliver a software update directly to the vehicle.<br><br>For example, a vehicle enters a workshop for a brief service such as changing tyres or replacing fluids, and relevant software updates are available. The software is delivered quickly via a direct C-V2X connection while other services are performed. This reduces total downtime and provides updates in a safe situation where technicians are available in case of anomaly, taking advantage of close range and unlicensed spectrum.<br><br>▸ Assumes a controlled environment such as a dealership/workshop, fuelling/charging station, or fleet parking facility.<br>▸ The download must be completed quickly with the car stationary, with systems powered on to handle the transfer and installation.<br>▸ The driver (human or robot) and technician (if applicable) are informed that a critical update is in progress and that the vehicle should not be powered down or driven until update completion.<br><br>Before the software transfer is initiated, the secure local RSU identifies the target vehicle(s) and the need for software updates. This process may be done through a bulletin published by the RSU which identifies vehicles needing specific updates |
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| User Story #1<br>Software Update (Conventional-Routine) | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | Within network service provider coverage | In principle, the User Story is applicable in the network service provider coverage area. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 1.5 GB within 168 hours | This is a current-day example of a major OEM update image that would be manually updated and installed today.<br><br>Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications. |
| **Service Level Latency** | **[ms]** | N/A | Software updates themselves are not latency-sensitive. |
| **Service Level Reliability** | **%** | 99 | Software updates should reliably and successfully transfer but this can occur over an extended period, as above.<br><br>Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range. |
| **Velocity** | **[m/s]** | 22.22 | Typical city speed (~80 km/h), where it will be helpful to collect software updates over time. Note that a consistent download rate is not required, since the download may collect parts of the software image as available and pause and continue downloading as needed. |

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| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Only a fraction of all vehicles would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. (e.g. < 15 vehicles/ km^2 typically need a specific update at a time). |
| **Positioning Accuracy** | **[m]** | 30 | It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road.<br>More precision could be helpful to validate that a vehicle is safely parked before an update installation begins, or whether it is within range of other communications mechanisms (e.g. home Wi-Fi). |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | No/Yes/No | We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates, and this will not be interoperable across manufacturers.<br>There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement.<br>Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers. |
| **User Story #2<br>Software Update (Conventional-Urgent)** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | Within network service provider coverage | In principle, the User Story is applicable in the network service provider coverage area. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 1.5 GB within 24 hours. | This is a current-day example of a major OEM update image that would be manually updated and installed today.<br>Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications. |
| **Service Level Latency** | **[ms]** | 1 hour to deliver | The most stringent requirement is to deliver the ‘critical update required’ message. The human driver is still responsible for safe vehicle operation.<br>Software updates themselves are not latency-sensitive. |

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| **Service Level Reliability** | **%** | 99 | Software updates should reliably and successfully transfer but this can occur over an extended period as above.<br>Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range. |
| **Velocity** | **[m/s]** | 22.22 | Typical city speed (~80 km/h), where it will be helpful to collect software updates over time. Note that a consistent download rate is not required, since the download may collect parts of the software image as available and pause and continue downloading as needed. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Only a fraction of all vehicles would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. E.g. <15 vehicles/km^2 typically need a specific update at a time.<br>We expect that <1 % of vehicles would need a specific software update at any given time. |
| **Positioning Accuracy** | **[m]** | 30 | It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road.<br>More precision could be helpful to validate that a vehicle is safely parked before an update installation begins or whether it is within range of other communications mechanisms (e.g. home Wi-Fi). |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | No/Yes/No | We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates and this will not be interoperable across manufacturers.<br>There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement.<br>Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers. |

| **User Story #3<br>Software Update (Autonomous-Routine)** | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | Within network service provider coverage | In principle, the User Story is applicable in the network service provider coverage area. |

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| **Information Requested/ Generated** | **Quality of information/ Information needs** | 3 GB within 24 hours | This is a conservative estimate of a current self-driving stack based on publicly-available information.<br><br>Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications. |
| **Service Level Latency** | **[ms]** | N/A | Software updates themselves are not latency-sensitive. |
| **Service Level Reliability** | **%** | 99 | Software updates should successfully transfer reliably but this can occur over an extended period as above.<br><br>Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range. |
| **Velocity** | **[m/s]** | 22.22 | Typical city speed (~80 km/h), where it will be helpful to collect software updates over time. Note that a consistent download rate is not required, since the download may collect parts of the software image as available and pause and continue downloading as needed. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Only a fraction of all vehicles would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. E.g. <15 vehicles/ km^2 typically need a specific update at a time.<br><br>We expect that <1 % of vehicles would need a specific software update at any given time. |
| **Positioning Accuracy** | **[m]** | 30 | It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road.<br><br>More precision could be helpful to validate that a vehicle is safely parked before an update installation begins, or whether it is within range of other communications mechanisms (e.g. home Wi-Fi). |

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| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | No/Yes/No | We expect individual vehicle manufacturers and 3rd party SW Update system developers will specify their own software updates and this will not be interoperable across manufacturers.<br>There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement.<br>However, the expectations for self-driving vehicles and corresponding regulations will require much greater urgency and may even include temporarily removing an affected vehicle from normal driving operations. Once the vehicle is parked, the urgency to apply the software update depends on commercial concerns such as the cost of vehicle downtime in an autonomous fleet.<br>Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers. |
| **User Story #4<br>Software Update (Autonomous-Urgent)** | | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | Within network service provider coverage | In principle, the Use Case is applicable in the network service provider coverage area. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 3 GB within 2 hours | This is a conservative estimate for a current self-driving stack based on publicly-available information.<br>Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications. |
| **Service Level Latency** | **[ms]** | 600,000 | The most stringent requirement is to deliver the 'critical update required' message, especially in the case of an autonomous vehicle. But even this is in the range of minutes.<br>Software updates themselves are not latency-sensitive. |
| **Service Level Reliability** | **%** | 99 | Software updates should reliably and successfully transfer but this can occur over an extended period, as above.<br>Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range. |

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| **Velocity** | **[m/s]** | 70 | This (250 km/h) is an allowed speed in some motorways and at least the 'critical update required' message should be deliverable at any speed the vehicle is likely to travel. Ideally, the download itself can be completed at this speed. Once the vehicle is parked and secured, installation can be completed over a longer period. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Only a fraction of all vehicles would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. E.g. <15 vehicles/km^2 typically need a specific update at a time.<br>We expect that <1 % of vehicles would need a specific software update at any given time. |
| **Positioning Accuracy** | **[m]** | 30 | It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road.<br>More precision could be helpful to validate that a vehicle is safely parked before an update installation begins or whether it is within range of other communications mechanisms (e.g. home Wi-Fi). |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | No/Yes/No | We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates and this will not be interoperable across manufacturers.<br>There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement.<br>However, the expectations for self-driving vehicles and corresponding regulations will require much greater urgency and may even include temporarily removing an affected vehicle from normal driving operations. Once the vehicle is parked, the urgency to apply the software update depends on commercial concerns such as the cost of vehicle downtime in an autonomous fleet.<br>Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers. |
| | **User Story #5<br>Software Update (Without Infrastructure)** | | |
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | <100 m between vehicles | This User Story assumes the vehicles are in close proximity. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 1.5 GB | This is a current-day example of a major OEM update image that would be manually updated and installed today. |
| **Service Level Latency** | **[ms]** | 30 seconds | The goal is to deliver updates vehicle-to-vehicle and minimise disruption to their regular activity. |

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| **Service Level Reliability** | **%** | 99 | Software updates should successfully transfer completely and reliably 99% of the time in the time desired above. |
| **Velocity** | **[m/s]** | 0 | We assume the vehicles will be parked in close proximity for this transfer. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum density in urban scenario. |
| **Positioning Accuracy** | **[m]** | 50 | Vehicles need to be in close proximity, and are expected to identify each other directly. |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | No/Yes/No | We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates and this will not be interoperable across manufacturers.<br><br>There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement.<br><br>Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers. |

| **User Story #6<br>Software Update (Vehicle to Workshop)** | | | |
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| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | <100 m between vehicle and RSU | Scenario is within a specific location and context as described. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 32 GB | This is a current-day example of a major OEM update package that today would be manually updated and installed. |
| **Service Level Latency** | **[ms]** | 900,000 | The goal is to deliver updates while other minor services such as tyre changes are performed. |
| **Service Level Reliability** | **%** | 99.9 | Software updates should successfully transfer reliably and within the desired timeframe. |
| **Velocity** | **[m/s]** | 0 m/s | We assume the vehicles will be parked during the download. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum of 100 vehicles to be updated at any one time within the facility. |
| **Positioning Accuracy** | **[m]** | 50 | Vehicles need to be in close proximity to the private C-V2X RSU. |

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| **Interoperability / Regulatory / Standardisation Required** | **[yes/no]** | No/Yes/No | We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates and this will not be interoperable across manufacturers.<br>There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement.<br>Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers. |

### 6.2.2 Vehicle Health Monitoring

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| **Use Case Name** | Vehicle Health Monitoring |
| **User Story** | Owners, fleet operators and authorised vehicle service providers monitor the health of HV and are alerted when maintenance or service is required |
| **Category** | Vehicle Operations Management |
| **Road Environment** | Intersection \| Urban \| Rural \| Highway \| Other |
| **Short Description** | ▸ Owners, operators and vehicle service providers request a report of the HVs current health including:<br>– On-board diagnostic trouble codes<br>– Predicted maintenance (fluids, brakes, tyres, battery, etc.)<br>▸ Owners, operators and vehicle service providers are alerted to new vehicle health issues requiring service and the vehicle's location when detecting:<br>– On-board diagnostic trouble codes<br>– Required maintenance (fluids, brakes, tyres, battery, etc.) |
| **Actors** | ▸ Host vehicle (HV)<br>▸ Vehicle owner<br>▸ Fleet operator<br>▸ Automotive service provider |
| **Vehicle Roles** | ▸ HV represents the vehicle that needs maintenance or service |
| **Roadside Infrastructure Roles** | N/A |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Provide owners, operators and vehicle service providers of HV health report on request<br>▸ Alert owners, operators and vehicle service providers of HV health issues requiring maintenance or service |
| **Needs** | ▸ Owners, operators and vehicle service providers need to know the health of the vehicle including:<br>– Required and estimated maintenance<br>– Detected problems that require service and the location of HV |
| **Constraints/ Presumptions** | N/A |

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| **Geographic Scope** | Global |
| **Illustrations** | N/A |
| **Pre-Conditions** | N/A |
| **Main Event Flow** | ▸ HV owner, operator or vehicle service provider requests a health report<br>▸ HV provides on-board diagnostic trouble codes<br>▸ Required maintenance is determined based on component use and wear<br>▸ A health report is provide to the requester |
| **Alternate Event Flow** | ▸ HV detects a problem using on-board diagnostics<br>▸ The HV owner, operator or vehicle service provider is notified of the detected on-board diagnostic trouble code |
| **Alternate Event Flow** | ▸ HV driver detects a problem that requires service<br>▸ The HV owner, operator or vehicle service provider is notified of the driver reported problem |
| **Alternate Event Flow** | ▸ A HV component requires maintenance based on determined use and wear<br>▸ The HV owner, operator or vehicle service provider is notified of the required maintenance |
| **Post-Conditions** | ▸ Owners, operators and vehicle service providers are aware of the health of the vehicle including:<br>– Required and estimated maintenance<br>– Detected problems that require service and location of HV |
| **Service Level Key Performance Indicators** | ▸ Location accuracy |
| **Information Requirements** | ▸ HV health report:<br>– On-board diagnostic trouble codes<br>– Predicted maintenance (fluids, brakes, tyres, battery, etc...)<br>– Required maintenance (fluids, brakes, tyres, battery, etc...)<br>▸ HV location |

| User Story | Detailed Description and Specifics |
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| **User Story #1** | A vehicle is travelling on a highway and is losing air pressure in one or more of its tyres. A road or fleet operator needs to be made aware of the situation. |

| User Story #1 | | | |
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| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | N/A | There is no concrete upper limit to the desired range. The vehicle needs to convey the message to the road operator or fleet manager cloud which in most cases is physically far away from the vehicle. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | <1 KB | The information must be timely and accurate. Since the information is safety related, it must be accurate. |

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| **Service Level Latency** | **[ms]** | < 30 s | Latency is not a critical factor. |
| **Service Level Reliability** | **%** | 99.99 | It is critical that the information be sent and received successfully. |
| **Velocity** | **[m/s]** | 44.4 | Health monitoring related events and messages should be able to be sent successfully at highway driving speeds (example 160 km/h). |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Maximum vehicle density in urban scenarios. |
| **Positioning Accuracy** | **[m]** | 1.5 m 3 ▯ (99.8%) | Since this information may be used to dispatch assistance, the location of the vehicle must be known within a lane width and within the vehicle's length. Here, 1.5 m is the typical accuracy required to locate a vehicle within a lane. |
| **Interoperability/ Regulatory/ Standardisation Required** | **[yes/no]** | Yes | Information should be standardised to enable road operators to identify vehicles that are at risk of becoming stranded and dispatch an appropriate level of assistance. |

## 6.3 Autonomous Driving

### 6.3.1 High Definition Sensor Sharing

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| **Use Case Name** | High Definition Sensor Sharing |
| **User Story/Use Case scenario** | The vehicle has automated driving mode and wants to execute manoeuvres |
| **Category** | Convenience, Autonomous Driving |
| **Road Environment** | Suburban \| Urban \| Highway \| Rural |
| **Short Description** | Vehicle uses its own sensors (e.g. HD camera, Lidar), and sensor information from other vehicles, to perceive its environment (e.g. come up with 3D model of world around it) and safely performs an automated driving manoeuvre |
| **Actors** | ▸ Host Vehicles (HV)<br>▸ Remote Vehicles (RV) |
| **Vehicle Roles** | ▸ On-board sensors detect other vehicles and objects<br>▸ On board processors calculate relative distances and trajectories of other vehicles<br>▸ Processed and/or un-processed information is shared with other vehicles |
| **Roadside Infrastructure Roles** | N/A |
| **Other Actors' Roles** | None |
| **Goal** | ▸ Automated driving manoeuvre safely performed |

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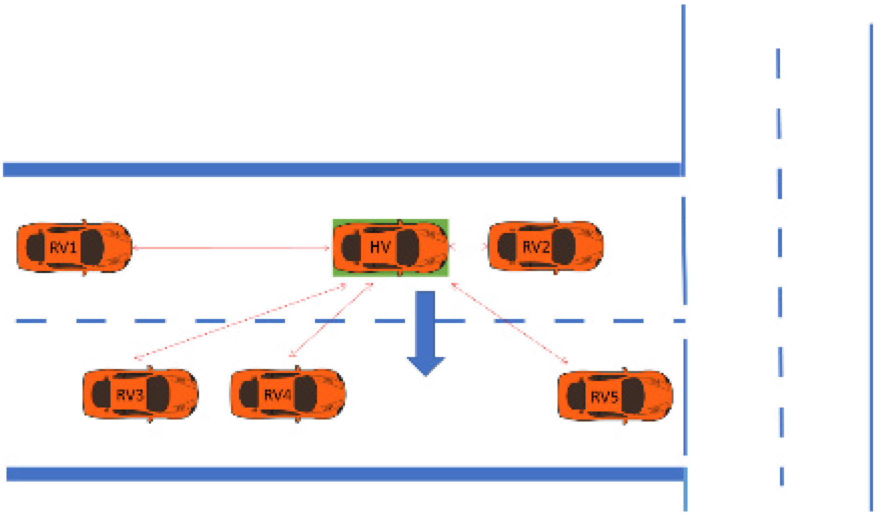
| **Needs** | ▸ Capability of vehicle to calculate accurately, and in real time, its relative position with other vehicles, road markings and objects<br>▸ Capability of the vehicle to use its own sensor information and/or that of other vehicles, including those not in line of sight<br>▸ System must work during the day and the night, and in all weather conditions |
| **Constraints/ Presumptions** | ▸ Not all vehicles will be equipped |
| **Geographic Scope** | Global |
| **Illustrations** |  |
| **Pre-Conditions** | ▸ Necessary software available in clients and applications<br>▸ Communication means available<br>▸ The HV has to understand the sensor data from the RVs, in an agreed format |
| **Main Event Flow** | ▸ HV captures 360 degree sensory information (e.g. other vehicles, road markings)<br>▸ HV calculates in real time its distance from other vehicles and objects, their relative positions and their trajectories<br>▸ HV receives processed and/or un-processed information (e.g. video) from RVs and uses that information to improve its perception of the surroundings and add certainty to its calculations<br>▸ HV, taking into account information received from RVs, calculates what the gap between RV4 and RV5 will be for the next n seconds. The HV knows from information received from RV5 that a junction is near and therefore it is likely to slow down imminently<br>▸ HV determines that it is safe to move from the left lane to the right lane<br>▸ HV notifies RVs of its intention<br>▸ HV performs the manoeuvre, adjusting its speed to the optimum |

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| **Alternative Event Flow** | ▸ As above except in step 3 the HV requests sensor information from specific RVs |
| **Post-Conditions** | ▸ The vehicle has moved from the left lane to the right lane |
| **Service Level Requirements** | See table below |
| **Information Requirements** | ▸ Accurate dynamic relative position and planned trajectory<br>▸ High-definition images<br>▸ Lidar<br>▸ Dynamic 3D absolute position<br>▸ Accuracy of the data and liability for sharing<br>▸ Agreed formats of data for sharing |

| User Story | Detailed Description and Specifics |
|---|---|
| **User Story #1** | Vehicle uses its own sensors (e.g. HD camera, Lidar), and sensor information from other vehicles, to perceive its environment (e.g. come up with 3D model of world around it) and safely performs an automated driving manoeuvre. |

| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 80 | 40 m is approximately 2 s driving time at 160 km/h, which should provide enough time for sensor sharing negotiation. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | Numerical | Processed and unprocessed data may be exchanged.<br>Near zero error rate tolerance (after error correction) on transmission link is required.<br>Max. 1000 B packet size (processed data). Larger for un-processed data. |
| **Service Level Latency** | **[ms]** | 10 | Lowest possible latency is needed to reduce reaction times of HV and RV.<br>10 ms is considered realistically achievable in Rel-16. |
| **Service Level Reliability** | **%** | 99.9 | Very high, the reliability here should be sufficient to guarantee QoS (whole system). |
| **Velocity** | **[m/s]** | 44.4 | Max. highway speed assumed to be 160 km/h. |
| **Vehicle Density** | **[vehicle/km^2]** | 12,000 | Max. assumed density in urban situation. |
| **Positioning Accuracy** | **[m]** | 0.1 | Relative between two vehicles. High accuracy is required to avoid collision. |

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| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes | Interoperability between manufacturers' implementations to be guaranteed by standardisation.<br>Processed sensor data shall be understandable between different manufactures' implementations. |

### 6.3.2 See-Through for Passing

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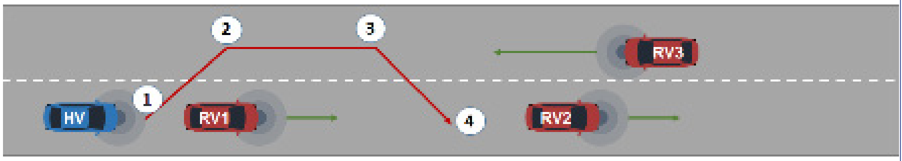
|---|---|
| **Use Case Name** | See-Through for Passing |
| **User Story** | The driver of HV that signals an intention to pass an RV using the oncoming traffic lane is provided a video stream showing the view in front of the RV |
| **Category** | Convenience \| Autonomous Driving |
| **Road Environment** | Rural two-lane highways |
| **Short Description** | ▸ HV approaches from behind or follows RV1 with the intention to pass using the oncoming lane<br>▸ Video stream of the front view of RV1 is shown to the HV driver during the passing manoeuvre |
| **Actors** | ▸ Host Vehicle (HV)<br>▸ Remote Vehicle 1 (RV1)<br>▸ Remote Vehicle 2 (RV2)<br>▸ Remote Vehicle 3 (RV3) |
| **Vehicle Roles** | ▸ HV represents the vehicle intending to pass RV1<br>▸ RV1 represents the vehicle being passed<br>▸ RV2 represents the vehicle in front of RV1<br>▸ RV3 represents the closest vehicle in the oncoming traffic lane |
| **Roadside Infrastructure Roles** | ▸ Roads must define their lanes and direction of traffic flow in each<br>▸ Road must indicate where passing is not permitted across traffic lanes |
| **Other Actors' Roles** | N/A |
| **Goal** | ▸ Provide HV driver a clear, reliable and real-time view of the road situation in front of the vehicle it is trying to pass and help avoid possible collision |
| **Needs** | ▸ Communication capabilities allowing real-time video transfer<br>▸ High-resolution display in HV |
| **Constraints / Presumptions** | ▸ HV and RV meet basic communications capabilities and performance requirements described for sending and receiving messages<br>▸ HV and RV are equipped to send and receive messages as well as high-bandwidth real-time video content |
| **Geographic Scope** | National |

| | |
|---|---|
| **Illustrations** | <br>▸ State 1 = HV starts receiving streaming video from RV1<br>▸ State 2 = HV has fully moved into the passing lane, continues receiving video streaming from RV1<br>▸ State 3 = HV has reached the position in the passing lane when it is ready to start the manoeuvre to return to the starting lane<br>▸ State 4 = HV completes the passing manoeuvre and can stop receiving the streaming video from RV1 |
| **Pre-Conditions** | ▸ HV is approaching from behind or following RV1<br>▸ The HV and RV are in communication range<br>▸ The RV is capable of collecting front facing visual information |
| **Trigger** | ▸ HV signals its intention to pass RV1<br>▸ HV driver requests visual of the RV1's front view |
| **Main Event Flow** | ▸ The HV is approaching the RV from behind in the same lane<br>▸ HV is following RV on a two-way road and makes a decision to initiate a passing manoeuvre.<br>▸ HV requests RV's visual information from its front view for the purpose of making a passing decision as well as additional information during the passing manoeuvre.<br>▸ The RV provides visual information from its front view periodically or event-based<br>▸ The HV receives the visual information from the RV<br>▸ The HV driver is able to see the RV front facing |
| **Alternative Event Flow** | None |
| **Post-Conditions** | ▸ Based upon the visual information from the RV, the HV driver is able to:<br>– Make an informed decision to overtake the RV when there is no traffic coming in on the opposite direction<br>– Complete a successful passing manoeuvre with the additional visual information from RV1 |
| **Service Level KPIs** | ▸ Velocity<br>▸ Data rate<br>▸ Range<br>▸ Latency<br>▸ Video quality |
| **Information Requirements** | ▸ Video streaming capability between vehicles as well as short message exchange capability |

| User Story | Detailed Description and Specifics |
|---|---|

| User Story #1 | Driver of the HV that signals an intention to pass an RV using the oncoming traffic lane is provided a video stream showing the view in front of the RV. |
|---|---|

| User Story #1 | | | |
|---|---|---|---|
| **SLR Title** | **SLR Unit** | **SLR Value** | **Explanations/Reasoning/Background** |
| **Range** | **[m]** | 100 | As the two vehicles concerned in the exchange of visual information are driving in the same lane, the communication range is from 50-100 *m*, considering a legal headway of 2 *s*. |
| **Information Requested/ Generated** | **Quality of information/ Information needs** | 15 Mbps | Video streaming.<br><br>15 Mbps are needed to transmit a progressive high-definition video signal with resolution 1280x720, frame rate 30 Hz, colour depth 8 bit, 24 bit resolution, subsampling 4:2:2 and a typical compression of 1:30 (e.g. with H.264). |
| **Service Level Latency** | **[ms]** | 50 | The latency requirement for a video frame depends on the vehicle speed and heading as well as pitch angle changes. Latency of 50 ms should be kept, lower values would increase the experience of this function. Additional delays would lead to additional buffering in the rear vehicle.<br><br>50 ms is the considered E2E communication layer latency, without including application layer processing times e.g. coding, de-coding.<br><br>Additional latency requirements:<br>▸ The duration of service discovery phase should be in maximum 500 ms (i.e. time duration for HV to identify if RV supports the see-through service). Service discovery includes the communication establishment phase (i.e. receive resources) as well as the discovery request and discovery response messages that HV and RV send, respectively<br>▸ The see-through establishment phase (i.e. a) HV asks for see-through and b) RV provides the first video frame) should complete within maximum within 500 ms<br>▸ Service discovery and see-through establishment within 1000 ms will help the driver of the HV to activate the requested see-through service quickly and take a fast decision whether to proceed within the overtake action. This also affects the engagement of the driver with the see-through application<br>▸ The see-through release phase should be complete within maximum 500 ms |

| | | | |
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| **Service Level Reliability** | **%** | 99 | Reliability of 99% at the communication layer for video frames is needed to avoid massive artefacts that may lead to degradation of video quality for assisted driving.<br>The video will be used to distinguish objects, front vehicles etc. in order to support a driver's decision to overtake or not. |
| **Velocity** | **[m/s]** | 33.33 | This is the maximum speed limit for non-urban streets (i.e. not highways).While 120 km/h is the maximum speed of the HV and RV.<br>Note: The transmitter of the video and the vehicle receiving the information will be more or less at the same speed 0-30 km/h (relative velocity). |
| **Vehicle Density** | **[vehicle/km^2]** | 9,000 | This type of service is most likely to be used in rural road environments.<br>Two vehicles are involved in this Use Case. |
| **Positioning Accuracy** | **[m]** | 1.5 (99.8%) | Positioning accuracy to know HV's and RV's location (including direction) and lane. |
| **Interoperability /Regulatory/ Standardisation Required** | **[yes/no]** | Yes/Yes/Yes | Interoperability is needed between the vehicles that participate in the see-through service.<br>Regulatory oversight for safety-related issues is needed.<br>Standardisation on the application layer (message set and flow control). |

## 6.4 Traffic Efficiency

### 6.4.1 Speed Harmonisation

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| **Use Case Name** | Speed Harmonisation |
| **User Story** | Notify a HV of a recommended speed to optimise traffic flow, minimise emissions and to ensure a smooth ride |
| **Category** | Traffic efficiency |
| **Road Environment** | Urban \| Rural \| Highway |
| **Short Description** | Notify HV of recommended speed based on traffic, road conditions and weather information. |
| **Actors** | ▸ Host vehicle (HV) |
| **Vehicle Roles** | ▸ The HV represents the vehicle receiving posted speed limits |
| **Road and Roadside Infrastructure Roles** | ▸ Roads are defined by their lane designations and geometry<br>▸ Posted speed limits are associated with road and lane segments |
| **Other Actors' Roles** | N/A |

| | |
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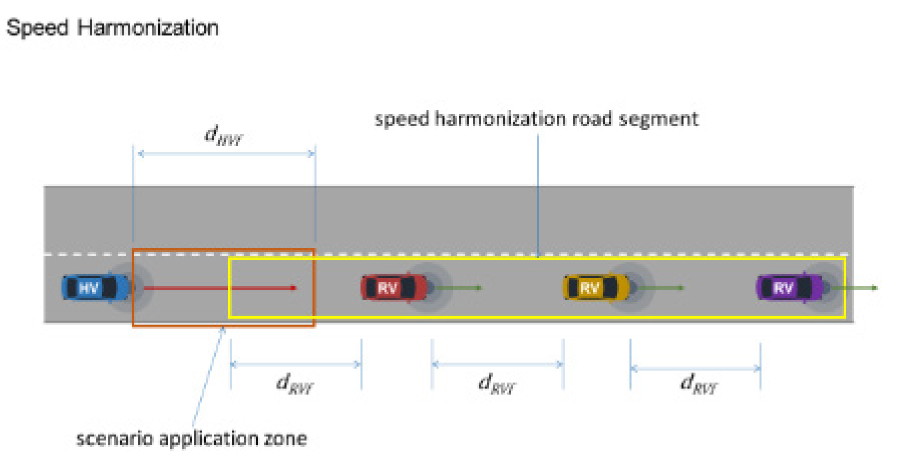
| **Goal** | ▸ Notify HV of the optimal speed to enable a comfortable ride and alleviate the need for frequent acceleration and deceleration<br>▸ Promote environmentally-friendly driving patterns<br>▸ Reduce risks of collisions due to stop and go traffic |
| **Needs** | HV needs to know the recommended speed to optimise traffic flow, minimise emissions and to ensure a smooth ride |
| **Constraints/ Presumptions** | ▸ RVs on the harmonised road segment are aware of the recommended speed |
| **Geographic Scope** | Global |
| **Illustrations** | <br><br>$d_{HVf}$ = safe following distance of HV<br>$d_{RVf}$ = safe following distance of RV |
| **Pre-Conditions** | ▸ HV is moving forward<br>▸ The scenario application zone is determined from:<br>– HV's location and dynamics<br>– HV's safe following distance<br>– lane designations and geometry<br>– posted speed limits<br>▸ The speed harmonisation road segment is determined from:<br>– RVs' location and dynamics<br>– RVs' safe following distance<br>– Lane designations and geometry<br>– Road conditions (if available) |
| **Main Event Flow** | ▸ If the 'speed harmonisation road segment' is in the scenario application zone:<br>– Notify HV of the recommended harmonised speed |
| **Post-Conditions** | ▸ HV is aware of the recommended harmonised speed |

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