3GPP TR 22.886 V16.2.0 (2018-12)

Technical Report

3rd Generation Partnership Project;

Technical Specification Group Services and System Aspects;

Study on enhancement of 3GPP Support for 5G V2X Services

(Release 16)

** 

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Keywords

V2X, eV2X, Vehicular communication

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Contents

Foreword [8](#__RefHeading___Toc533173566)

1 Scope [9](#__RefHeading___Toc533173567)

2 References [9](#__RefHeading___Toc533173568)

3 Definitions and abbreviations [11](#__RefHeading___Toc533173569)

3.1 Definitions [11](#__RefHeading___Toc533173570)

3.2 Abbreviations [12](#__RefHeading___Toc533173571)

4 Overview [12](#__RefHeading___Toc533173572)

5 Use cases [13](#__RefHeading___Toc533173573)

5.1 eV2X support for vehicle platooning [13](#__RefHeading___Toc533173574)

5.1.1 Description [13](#__RefHeading___Toc533173575)

5.1.2 Potential requirements [13](#__RefHeading___Toc533173576)

5.2 Information exchange within platoon [14](#__RefHeading___Toc533173577)

5.2.1 Description [14](#__RefHeading___Toc533173578)

5.2.1.1 General [14](#__RefHeading___Toc533173579)

5.2.1.2 Pre-conditions [15](#__RefHeading___Toc533173580)

5.2.1.3 Service flows [15](#__RefHeading___Toc533173581)

5.2.1.4 Post-conditions [15](#__RefHeading___Toc533173582)

5.2.2 Potential requirements [15](#__RefHeading___Toc533173583)

5.3 Automotive: sensor and state map sharing [15](#__RefHeading___Toc533173584)

5.3.1 Description [15](#__RefHeading___Toc533173585)

5.3.1.1 General [15](#__RefHeading___Toc533173586)

5.3.1.2 Pre-conditions [16](#__RefHeading___Toc533173587)

5.3.1.3 Service flows [16](#__RefHeading___Toc533173588)

5.3.1.4 Post-conditions [16](#__RefHeading___Toc533173589)

5.3.2 Potential requirements [16](#__RefHeading___Toc533173590)

5.4 eV2X support for remote driving [17](#__RefHeading___Toc533173591)

5.4.1 Description [17](#__RefHeading___Toc533173592)

5.4.2 Potential requirements [17](#__RefHeading___Toc533173593)

5.5 Automated cooperative driving for short distance grouping [18](#__RefHeading___Toc533173594)

5.5.1 Description [18](#__RefHeading___Toc533173595)

5.5.1.1 General [18](#__RefHeading___Toc533173596)

5.5.1.2 Pre-conditions [19](#__RefHeading___Toc533173597)

5.5.1.3 Service flows [19](#__RefHeading___Toc533173598)

5.5.1.4 Post-conditions [20](#__RefHeading___Toc533173599)

5.5.2 Potential requirements [20](#__RefHeading___Toc533173600)

5.6 Collective perception of environment [20](#__RefHeading___Toc533173601)

5.6.1 Description [20](#__RefHeading___Toc533173602)

5.6.1.1 General [20](#__RefHeading___Toc533173603)

5.6.1.2 Pre-conditions [21](#__RefHeading___Toc533173604)

5.6.1.3 Service flows [22](#__RefHeading___Toc533173605)

5.6.1.4 Post-conditions [22](#__RefHeading___Toc533173606)

5.6.2 Potential requirements [22](#__RefHeading___Toc533173607)

5.7 Communication between vehicles of different 3GPP RATs [22](#__RefHeading___Toc533173608)

5.7.1 Description [22](#__RefHeading___Toc533173609)

5.7.2 Potential requirements [24](#__RefHeading___Toc533173610)

5.8 Multi-PLMN environment [24](#__RefHeading___Toc533173611)

5.8.1 Description [24](#__RefHeading___Toc533173612)

5.8.1.1 General [24](#__RefHeading___Toc533173613)

5.8.1.2 Pre-conditions [24](#__RefHeading___Toc533173614)

5.8.1.3 Service flows [24](#__RefHeading___Toc533173615)

5.8.1.4 Post-conditions [24](#__RefHeading___Toc533173616)

5.8.2 Potential requirements [24](#__RefHeading___Toc533173617)

5.9 Cooperative collision avoidance (CoCA) of connected automated vehicles [25](#__RefHeading___Toc533173618)

5.9.1 Description [25](#__RefHeading___Toc533173619)

5.9.1.1 General [25](#__RefHeading___Toc533173620)

5.9.1.2 Pre-conditions [25](#__RefHeading___Toc533173621)

5.9.1.3 Service flows [25](#__RefHeading___Toc533173622)

5.9.1.4 Post-conditions [25](#__RefHeading___Toc533173623)

5.9.2 Potential requirements [25](#__RefHeading___Toc533173624)

5.10 Information sharing for partial/ conditional automated driving [26](#__RefHeading___Toc533173625)

5.10.1 Description [26](#__RefHeading___Toc533173626)

5.10.1.1 General [26](#__RefHeading___Toc533173627)

5.10.1.2 Pre-conditions [26](#__RefHeading___Toc533173628)

5.10.1.3 Service flows [27](#__RefHeading___Toc533173629)

5.10.1.4 Post-conditions [27](#__RefHeading___Toc533173630)

5.10.2 Potential requirements [27](#__RefHeading___Toc533173631)

5.11 Information sharing for high/full automated driving [28](#__RefHeading___Toc533173632)

5.11.1 Description [28](#__RefHeading___Toc533173633)

5.11.1.1 General [28](#__RefHeading___Toc533173634)

5.11.1.2 Pre-conditions [28](#__RefHeading___Toc533173635)

5.11.1.3 Service flows [28](#__RefHeading___Toc533173636)

5.11.1.4 Post-conditions [29](#__RefHeading___Toc533173637)

5.11.2 Potential requirements [29](#__RefHeading___Toc533173638)

5.12 Information sharing for partial/ conditional automated platooning [29](#__RefHeading___Toc533173639)

5.12.1 Description [29](#__RefHeading___Toc533173640)

5.12.1.1 General [29](#__RefHeading___Toc533173641)

5.12.1.2 Pre-conditions [30](#__RefHeading___Toc533173642)

5.12.1.3 Service flows [30](#__RefHeading___Toc533173643)

5.12.1.4 Post-conditions [30](#__RefHeading___Toc533173644)

5.12.2 Potential requirements [31](#__RefHeading___Toc533173645)

5.13 Information sharing for high/full automated platooning [31](#__RefHeading___Toc533173646)

5.13.1 Description [31](#__RefHeading___Toc533173647)

5.13.1.1 General [31](#__RefHeading___Toc533173648)

5.13.1.2 Pre-conditions [32](#__RefHeading___Toc533173649)

5.13.1.3 Service flows [32](#__RefHeading___Toc533173650)

5.13.1.4 Post-conditions [32](#__RefHeading___Toc533173651)

5.13.2 Potential requirements [32](#__RefHeading___Toc533173652)

5.14 Dynamic ride sharing [33](#__RefHeading___Toc533173653)

5.14.1 Description [33](#__RefHeading___Toc533173654)

5.14.1.1 General [33](#__RefHeading___Toc533173655)

5.14.1.2 Pre-conditions [33](#__RefHeading___Toc533173656)

5.14.1.3 Service flows [33](#__RefHeading___Toc533173657)

5.14.1.4 Post-conditions [34](#__RefHeading___Toc533173658)

5.14.2 Potential requirements [34](#__RefHeading___Toc533173659)

5.15 Use case on multi-RAT [34](#__RefHeading___Toc533173660)

5.15.1 Description [34](#__RefHeading___Toc533173661)

5.15.2 Potential requirements [34](#__RefHeading___Toc533173662)

5.16 Video data sharing for assisted and improved automated driving (VaD) [34](#__RefHeading___Toc533173663)

5.16.1 Description [34](#__RefHeading___Toc533173664)

5.16.1.1 General [34](#__RefHeading___Toc533173665)

5.16.1.2 Pre-conditions [35](#__RefHeading___Toc533173666)

5.16.1.3 Service flows [35](#__RefHeading___Toc533173667)

5.16.1.4 Post-conditions [35](#__RefHeading___Toc533173668)

5.16.2 Potential requirements [35](#__RefHeading___Toc533173669)

5.17 Changing driving-mode [36](#__RefHeading___Toc533173670)

5.17.1 Description [36](#__RefHeading___Toc533173671)

5.17.1.1 General [36](#__RefHeading___Toc533173672)

5.17.1.2 Pre-conditions [36](#__RefHeading___Toc533173673)

5.17.1.3 Service flows [37](#__RefHeading___Toc533173674)

5.17.1.4 Post-conditions [37](#__RefHeading___Toc533173675)

5.17.2 Potential requirements [37](#__RefHeading___Toc533173676)

5.18 Tethering via Vehicle [38](#__RefHeading___Toc533173677)

5.18.1 Description [38](#__RefHeading___Toc533173678)

5.18.1.1 General [38](#__RefHeading___Toc533173679)

5.18.1.2 Pre-conditions [38](#__RefHeading___Toc533173680)

5.18.1.3 Service flows [38](#__RefHeading___Toc533173681)

5.18.1.4 Post-conditions [39](#__RefHeading___Toc533173682)

5.18.2 Potential requirements [39](#__RefHeading___Toc533173683)

5.19 Use case out of 5G coverage [39](#__RefHeading___Toc533173684)

5.19.1 Description [39](#__RefHeading___Toc533173685)

5.19.2 Potential requirements [40](#__RefHeading___Toc533173686)

5.20 Emergency trajectory alignment [40](#__RefHeading___Toc533173687)

5.20.1 Description [40](#__RefHeading___Toc533173688)

5.20.1.1 General [40](#__RefHeading___Toc533173689)

5.20.1.1 Pre-conditions [40](#__RefHeading___Toc533173690)

5.20.1.2 Service flows [40](#__RefHeading___Toc533173691)

5.20.1.3 Post-conditions [41](#__RefHeading___Toc533173692)

5.20.2 Potential requirements [41](#__RefHeading___Toc533173693)

5.21 Teleoperated support (TeSo) [41](#__RefHeading___Toc533173694)

5.21.1 Description [41](#__RefHeading___Toc533173695)

5.21.1.1 General [41](#__RefHeading___Toc533173696)

5.21.1.2 Pre-conditions [41](#__RefHeading___Toc533173697)

5.21.1.3 Service flows [42](#__RefHeading___Toc533173698)

5.21.1.4 Post-conditions [42](#__RefHeading___Toc533173699)

5.21.2 Potential requirements [42](#__RefHeading___Toc533173700)

5.22 Intersection safety information provisioning for urban driving [42](#__RefHeading___Toc533173701)

5.22.1 Description [42](#__RefHeading___Toc533173702)

5.22.1.1 General [42](#__RefHeading___Toc533173703)

5.22.1.2 Pre-conditions [43](#__RefHeading___Toc533173704)

5.22.1.3 Service flows [43](#__RefHeading___Toc533173705)

5.22.1.4 Post-conditions [44](#__RefHeading___Toc533173706)

5.22.1.5 Potential impacts or interactions with existing services/features [44](#__RefHeading___Toc533173707)

5.22.2 Potential requirements [44](#__RefHeading___Toc533173708)

5.23 Cooperative lane change (CLC) of automated vehicles [44](#__RefHeading___Toc533173709)

5.23.1 Description [44](#__RefHeading___Toc533173710)

5.23.1.1 General [44](#__RefHeading___Toc533173711)

5.23.1.2 Pre-conditions [45](#__RefHeading___Toc533173712)

5.23.1.3 Service flows [45](#__RefHeading___Toc533173713)

5.23.1.4 Post-conditions [45](#__RefHeading___Toc533173714)

5.23.2 Potential requirements [45](#__RefHeading___Toc533173715)

5.24 Proposal for secure software update for electronic control unit [45](#__RefHeading___Toc533173716)

5.24.1 Description [45](#__RefHeading___Toc533173717)

5.24.1.1 General [45](#__RefHeading___Toc533173718)

5.24.1.1 Pre-conditions [45](#__RefHeading___Toc533173719)

5.24.1.2 Service flows [46](#__RefHeading___Toc533173720)

5.24.1.3 Post-conditions [46](#__RefHeading___Toc533173721)

5.24.2 Potential requirements: [46](#__RefHeading___Toc533173722)

5.25 3D video composition for V2X scenario [46](#__RefHeading___Toc533173723)

5.25.1 Description [46](#__RefHeading___Toc533173724)

5.25.2 Potential requirements [47](#__RefHeading___Toc533173725)

5.26 QoS aspect of vehicles platooning [47](#__RefHeading___Toc533173726)

5.26.1 General description [47](#__RefHeading___Toc533173727)

5.26.2 Adjustment of gaps for platooning [47](#__RefHeading___Toc533173728)

5.26.2.1 Description [47](#__RefHeading___Toc533173729)

5.26.2.2 Potential requirements [48](#__RefHeading___Toc533173730)

5.27 QoS aspects of advanced driving [48](#__RefHeading___Toc533173731)

5.27.1 General [48](#__RefHeading___Toc533173732)

5.27.2 Assistance to automated driving [49](#__RefHeading___Toc533173733)

5.27.2.1 Service flows [49](#__RefHeading___Toc533173734)

5.27.2.2 Potential Requirements [49](#__RefHeading___Toc533173735)

5.27.3 Authorization to support automated driving [49](#__RefHeading___Toc533173736)

5.27.3.1 Service flows [49](#__RefHeading___Toc533173737)

5.27.3.2 Potential Requirements [50](#__RefHeading___Toc533173738)

5.27.4 Notification of updated information to support automated driving [50](#__RefHeading___Toc533173739)

5.27.4.1 Service flows [50](#__RefHeading___Toc533173740)

5.27.4.2 Potential Requirements [50](#__RefHeading___Toc533173741)

5.27.5 Support for adjustment and big data transport [51](#__RefHeading___Toc533173742)

5.27.5.1 Service flows [51](#__RefHeading___Toc533173743)

5.27.5.2 Potential Requirements [51](#__RefHeading___Toc533173744)

5.27.6 Support of automated driving in multi-PLMN environments [51](#__RefHeading___Toc533173745)

5.27.6.1 Service flows [51](#__RefHeading___Toc533173746)

5.27.6.2 Potential Requirements [52](#__RefHeading___Toc533173747)

5.27.7 Reliable and guaranteed connectivity service [52](#__RefHeading___Toc533173748)

5.27.7.1 Service flows [52](#__RefHeading___Toc533173749)

5.27.7.2 Potential Requirements [53](#__RefHeading___Toc533173750)

5.28 QoS aspect of remote driving [53](#__RefHeading___Toc533173751)

5.28.1 Notification of QoS change for remote driving application [53](#__RefHeading___Toc533173752)

5.28.1.1 Description [53](#__RefHeading___Toc533173753)

5.28.1.2 Pre-conditions [53](#__RefHeading___Toc533173754)

5.28.1.3 Service Flows [54](#__RefHeading___Toc533173755)

5.28.1.4 Post-conditions [54](#__RefHeading___Toc533173756)

5.28.1.5 Potential Requirements [54](#__RefHeading___Toc533173757)

5.28.2 Support of remote Driving [54](#__RefHeading___Toc533173758)

5.28.2.1 General [54](#__RefHeading___Toc533173759)

5.28.2.2 Disengagement of autonomous driving [54](#__RefHeading___Toc533173760)

5.28.2.3 Provision of freedom of mobility [55](#__RefHeading___Toc533173761)

5.28.2.4 Potential requirements [55](#__RefHeading___Toc533173762)

5.29 QoS Aspect for extended sensor [56](#__RefHeading___Toc533173763)

5.29.1 Description [56](#__RefHeading___Toc533173764)

5.29.1.1 Pre-conditions [56](#__RefHeading___Toc533173765)

5.29.1.2 Service Flow [57](#__RefHeading___Toc533173766)

5.29.1.3 Post-conditions [57](#__RefHeading___Toc533173767)

5.29.2 Potential Requirements [57](#__RefHeading___Toc533173768)

5.30 Different QoS estimation for different V2X applications [57](#__RefHeading___Toc533173769)

5.30.1 Description [57](#__RefHeading___Toc533173770)

5.30.1.1 Pre-conditions [58](#__RefHeading___Toc533173771)

5.30.1.2 Service Flow [58](#__RefHeading___Toc533173772)

5.30.1.3 Post-conditions [59](#__RefHeading___Toc533173773)

5.30.2 Potential Requirements [59](#__RefHeading___Toc533173774)

6 Considerations [60](#__RefHeading___Toc533173775)

6.1 Considerations on network slicing [60](#__RefHeading___Toc533173776)

6.2 Considerations on deployment and mobility [60](#__RefHeading___Toc533173777)

6.3 Considerations on relation to requirements of LTE V2X [60](#__RefHeading___Toc533173778)

7 Potential requirements [61](#__RefHeading___Toc533173779)

7.1 General [61](#__RefHeading___Toc533173780)

7.2 Consolidated requirements [61](#__RefHeading___Toc533173781)

7.2.1 General requirements [61](#__RefHeading___Toc533173782)

7.2.2 Requirements for platooning [62](#__RefHeading___Toc533173783)

7.2.3 Requirements for advanced driving [64](#__RefHeading___Toc533173784)

7.2.4 Requirements for extended sensors [65](#__RefHeading___Toc533173785)

7.2.5 Requirements for remote driving [65](#__RefHeading___Toc533173786)

7.2.6 Requirements for vehicle quality of service support [66](#__RefHeading___Toc533173787)

8 Conclusion and recommendations [68](#__RefHeading___Toc533173788)

Annex A: Mapping of use cases to use case group [69](#__RefHeading___Toc533173789)

Annex B: Mapping table between PRs and CPRs [71](#__RefHeading___Toc533173790)

Annex C: Other considered use cases [74](#__RefHeading___Toc533173791)

C.1 Interoperability with other V2X schemes [74](#__RefHeading___Toc533173792)

C.1.1 Description [74](#__RefHeading___Toc533173793)

C.1.1.1 General [74](#__RefHeading___Toc533173794)

C.1.1.2 Pre-conditions [74](#__RefHeading___Toc533173795)

C.1.1.3 Service flows [74](#__RefHeading___Toc533173796)

C.1.1.4 Post-conditions [74](#__RefHeading___Toc533173797)

Annex D: Change history [75](#__RefHeading___Toc533173798)

# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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# 1 Scope

The objective of this document is to identify use cases and potential service requirements to enhance 3GPP support for V2X service in the following areas:

- Support for non-safety V2X services (also, referred to as "comfort service") (e.g. connected vehicle, mobile high data rate entertainment, mobile hot-spot/office/home, dynamic digital map update)

- Support for safety-related V2X services (e.g. autonomous driving, car platooning, priority handling between safety-related V2X services and other services)

- Support for V2X services in multiple 3GPP RATs (e.g. LTE, New RAT (NR)) and networks environment, including aspects such as interoperability with non-3GPP V2X technology (e.g. ITS-G5, DSRC, ITS-Connect)

In this document, V2X-related use cases and potential requirements already included in TR 22.891 are considered and new ones are introduced.

The identification of use cases and potential requirements covers both evolved LTE RAT and new 3GPP RAT (e.g. NR) and also covers V2X operation using 3GPP RATs where there are non-3GPP V2X technologies (e.g. ITS-G5, DSRC, ITS-Connect) in use.

# 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 non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

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# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply.   
A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**End-to-end latency:** time it takes to transfer a given piece of information from a source to a destination, measured at the application level, from the moment it is transmitted by the source to the moment it is received at the destination.

**Road Side Unit:** A stationary infrastructure entity supporting V2X applications that can exchange messages with other entities supporting V2X applications.

NOTE: RSU is a term frequently used in existing ITS specifications, and the reason for introducing the term in the 3GPP specifications is to make the documents easier to read for the ITS industry. RSU is a logical entity that supports V2X application logic using the functionality providedby either a 3GPP network or an UE (referred to as UE-type RSU).

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.   
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

CACC Cooperative Adaptive Cruise Control

LoA Level of Automation

RSU Road Side Unit

V2I Vehicle to Infrastructure

V2V Vehicle to Vehicle

# 4 Overview

A basic set of requirements for EPS to support V2X applications have been specified in [25]. These requirements are considered sufficient for vehicles (i.e., UEs supporting V2X applications) to exchange their own status information, such as position, speed and heading, with other nearby vehicles, infrastructure nodes and/or pedestrians. Also, these requirements fulfil the need to disseminate imminent warning messages to nearby entities in time. The capability of EPS to support these requirements will expedite the adoption of 3GPP connectivity by vehicles.

Despite the basic set of requirements for 3GPP system to support V2X service, it is considered growingly important among telecommunication industry and automotive industry that its evolution is necessary. Because automotive industries have begun to see V2X applications beyond unidirectional distribution of status information of vehicles, the 3GPP system needs to increase its capability enough to meet KPIs that emerging V2X applications require. That is, as V2X applications advance, transmission of short messages about vehicles’ own status data will be complemented with transmission of larger messages containing raw sensor data, vehicles’ intention data, coordination and confirmation of future manoeuvre and so on. For these advanced applications, the expected requirements to meet the needed data rate, reliability, latency, communication range and speed are made more stringent.

A relevant aspect of advanced V2X applications is the Level of Automation (LoA), which reflects the functional aspects of the technology and affects the system performance requirements. In accordance with the levels from SAE [X1] and NHTSA [X2], the LoA are: 0 – No Automation, 1 – Driver Assistance, 2 – Partial Automation, 3 – Conditional Automation, 4 – High Automation, 5 – Full Automation. A distinction is drawn between Levels 0-2 (Driver Control) and 3-5 (Vehicle Control) based on whether the human operator or the automated system is primarily responsible for monitoring the driving environment.

# 5 Use cases

## 5.1 eV2X support for vehicle platooning

### 5.1.1 Description

Platooning is operating a group of vehicles in a closely linked manner so that the vehicles move like a train with virtual strings attached between vehicles. To maintain distance between vehicles, the vehicles needs to share status information such as speed, heading and intentions such as braking, acceleration, etc. By use of platooning, the distances between vehicles can be reduced, overall fuel consumption is lowered, and the number of needed drivers can be reduced.

Following aspects need to be supported for platooning.

Join/Leave

To form a platoon, vehicles need to exchange intent such as interest to form a platoon, intention to be a leader or follower of the platoon. And when a vehicle reaches a destination or has to leave the platoon, this intent should be also exchanged among vehicles of the platoon. This exchange of intent can occur at any time while the platoon is active.

Announcement/Warning

When a platoon is formed and operational, a vehicle which do not belong to the platoon should aware the existence of the platoon. Otherwise, the vehicle may move into the middle of the platoon and disrupt the operation of the platoon. Thus, the platoon should be known to other vehicles beyond the communication range among vehicles of the same platoon.

Group communication

There are several messages that are exchanged for platoon management. E.g., vehicles of the platoon need to exchange information regarding when to take which road, whether to brake or accelerate and when, etc. At least, 30 CAM messages/seconds needs to be supported. [3]. In addition, the lead vehicle consume more fuel than other vehicles, sometime lead vehicle may request next vehicle to be a leader. This kind of communication can be done between the two vehicles without other vehicles’ involvement.

To prevent potential security threats such as revealing of the route, these messages should be supported with confidentiality and be deciphered only by the vehicles of the platoon. In addition, due to the private nature of the messages, the communication range of these messages is from the lead vehicle to the last vehicle of the platoon, and typically line-of-sight. Because the size of the platoon can differ even on the move, resource-efficient distribution of messages for platooning and dynamic control of the distribution area of the messages should be supported.

Two sets of Platooning performances requirements are supported:

- Set 1: According to [11][2], the distance between vehicles for normal density platooning may be larger than 2 meters. When the platoon moves at 100km/h, vehicles move 1 meter in 36ms. Considering the round-trip-time and processing delay, message transmission frequency up to 40Hz, translating into 25ms end-to-end latency with message sizes of around 300-400 bytes should be supported.

- Set 2: According to [2], the distance between vehicles for high density platooning is 1 meter. When the platoon moves at 100 km/h, vehicles move 1 meter in 36 ms. Considering round-trip-time and processing delay, message transmission frequency up to 100 Hz, translating into at least 10 ms latency with message sizes of around 50-1200 bytes should be supported.

If the platoon is too long, it will sometimes interrupt the operation of other vehicles and traffic management authority. So, there should be limit on how many vehicles can be included in a platoon. This is especially true considering that a truck can span more than 15 m.

### 5.1.2 Potential requirements

The following potential requirements are derived from this use case:

KPIs common for set 1 and set 2:

[PR.5.1-001] The 3GPP system shall be able to control the communication range for a message based on the characteristic of the messages transmitted by a UE supporting V2X application.

[PR.5.1-002] The 3GPP system shall be able to support in a periodic manner at least 30 message per second broadcast by a UE supporting V2X application.

[PR.5.1-003] The 3GPP system shall be able to create/destroy a group for UEs supporting V2X application.

[PR.5.1-004] The 3GPP system shall be able to support up to 5 UEs for a group of UEs supporting V2X application.

[PR.5.1-005] The 3GPP system shall be able to add/remove a UE supporting V2X application into a group of UEs supporting V2X application.

[PR.5.1-006] The 3GPP system shall be able to support at least in a periodic manner [28] message transfer per second among a group of UEs supporting V2X application.

[PR.5.1-007] The 3GPP system shall be able to support message transfer among a group of UEs supporting V2X application.

[PR.5.1-008] The 3GPP system shall be able to support message transfer between two UEs belonging to the same group of UEs supporting V2X application.

[PR.5.1-009] The 3GPP system shall be able to support confidentiality and integrity of message transfer among a group of UEs supporting V2X application.

KPIs for set 2:

[PR.5.1-010] The 3GPP system shall be able to support 10 ms end-to-end latency for message transfer among a group of UEs supporting V2X application.

[PR.5.1-011] The 3GPP system shall be capable of transferring messages among a group of UEs supporting V2X application with variable message payloads of 50-1200 bytes, not including security-related message component.

KPIs for set 1:

[PR.5.1-012] The 3GPP system shall support communication latency no larger than [25] ms.

[PR.5.1-013] The 3GPP system shall support [90] % reliability.

[PR.5.1-014] The 3GPP system shall support triggered and periodic transmission of small data packets (e.g. 300-400 bytes).

## 5.2 Information exchange within platoon

### 5.2.1 Description

#### 5.2.1.1 General

When the vehicles are travelling on the road, they can dynamically form a platoon. The platoon creator is responsible for platoon management. The manager should real-time updates surrounding traffic data reported by group members, and reported it to RSU; At the same time, the platoon manager should real-time receive RSU messages which include road conditions and traffic information far away from them, and share them with platoon members. All the platoon members can also share the information within the group through V2V.

All the platoon members can obtain information through two ways. One is within platoon through V2V. Another is come from RSU which based on the platoon manager relay. All the information obtains will be used to build high-precision dynamic driving maps. Information exchange between vehicles can be the new type of "ask-response".

#### 5.2.1.2 Pre-conditions

All the vehicles support V2V communication and the platoon manager should support V2V and V2I communication. Each vehicle has a unique label for identification when interacting with others.

The platoon has more than 1 active vehicle which is driving in the same lane. All the platoon members are within the communication range with its direct neighbour which also is the platoon member.

The platoon management is responsible for platoon management and information exchange with the RSU.

#### 5.2.1.3 Service flows

Vehicle A/B/C/D are within the same platoon, and vehicle A is the team manager.

Vehicle A/B/C/D sharing the surrounding real-time traffic and road information within the platoon. Vehicle A reports all the information to RSU.

Vehicle A receives traffic and road information from RSU, found there are road congestion caused by traffic accidents in the front corner of the road which are out of their V2V communication range.

Vehicle A sharing the information to vehicle B/C/D. Vehicle B/C/D update the driving map in real time and the platoon slow down and change the route.

#### 5.2.1.4 Post-conditions

Vehicles within platoon can build the high-precision dynamic driving map by real-time sharing information with platoon members which can provide reliable protection for traffic safety and efficiency.

Vehicles which only support V2V can obtain dynamic information out of the V2V communication range through platoon information exchange.

Also the vehicles without HD camera and radar can obtain the surrounding information from other platoon members.

### 5.2.2 Potential requirements

[PR.5.2-001] The 3GPP system shall be able to support a maximum latency of [500] ms for the transport of V2X messages between a UE supporting V2X application and a RSU via another UE supporting V2X application.

[PR.5.2-002] The 3GPP system shall be able to support the maximum transport of [2] V2X messages per second between a UE supporting V2X application and a RSU via another UE supporting V2X application..

[PR.5.2-003] The 3GPP system shall be able to support the transport of V2X messages with variable payload of [50-1200] bytes between a UE supporting V2X application and a RSU via another UE supporting V2X application.

[PR.5.2-004] The 3GPP system shall be able to support a maximum latency of [10] ms for V2V communications.

## 5.3 Automotive: sensor and state map sharing

### 5.3.1 Description

#### 5.3.1.1 General

Sensor and state map sharing (SSMS) enables sharing of raw or processed sensor data to build collective situational awareness. The concept is an extension of the Local Dynamic Map embodied in ETSI and ISO technical reports and standards [4], [5], [6], [7] with the primary difference being higher spatio-temporal fidelity, low latency and ability to transition from hyper-local to transportation link to network area of "state map" awareness. Sensor and state map sharing would leverage properties of highly-reliable transmission and system resiliency. This enables services such as low latency communication for precision positioning and control; such properties can enable mission critical applications such as cooperative driving (vehicle platooning), intersection safety of all road users to include pedestrians and emergency vehicle communication. For these use cases, highly resolved sensor images do not necessarily need to be transmitted (see [8] where smart nodes perform on-board processing and data exchange for a shared or fused situational awareness, whereupon vehicles autonomously perform reasoning or tactical manoeuvre planning operations); however, because of the plethora of disparate connected sensors, it is anticipated that significant data bandwidth would be needed for SSMS.

Requirements:

- High bandwidth

- High reliability for fusion confidence

- Short latency to allow highly dynamic automated vehicle operation and emergency vehicle response

- High density of transmitting devices

- Large messages

- Integration of network and cloud-based information (e.g. local dynamic map.)

High precision positioning techniques should also be supported (either via local sharing, ranging or from the mobile network) because GPS may not available in dense urban scenario.

#### 5.3.1.2 Pre-conditions

1. Vehicles A, B and C are SSMS-enabled. Infrastructure appurtenances (constituting roadside equipment or RSE) X, Y and Z are SSMS-enabled.

2. Any combination of vehicles A, B and C and RSE X, Y and Z are in communication range

3. At least two entities within A, B, C, X, Y or Z offers SSMS services, effectively creating a SSMS group.

#### 5.3.1.3 Service flows

1. SSMS group members (A, B, C, X, Y, Z) share messages with common data exchange format (e.g, future extended Local Dynamic Map). This information would include the vehicle trajectory, its planned trajectory and some combination of raw or processed/abstracted data from on-board perception sensors.

2. SSMS group member develops individual state map.

3. SSMS group member makes tactical or manoeuvre decision based on state map.

4. SSMS group member broadcasts manoeuvre decision to all others in SSMS group.

5. SSMS group member conducts manoeuvre decision.

6. Other SSMS group members incorporate manoeuvre decision broadcast and their sensors’ perception of group member manoeuvre into their state maps.

#### 5.3.1.4 Post-conditions

1. Enhanced state information: SSMS group members (A, B, C, X, Y, Z) are enabled to perform their individual movement (A, B, C) and system and roadway (X, Y, Z) operations and control functions with high degree of individual and shared situational awareness.

2. System coordination: Enables SSMS group members to perform joint operational instructions.

3. Improved safety and operational performance.

### 5.3.2 Potential requirements

All requirements are for end to end performance, defined as communications sent by source and communication received by target.

[PR.5.3-001] The 3GPP system shall support less than 10 ms latency between V2X applications.

[PR.5.3-002] The 3GPP system shall support message reliability of 90 % between V2X applications.

[PR.5.3-003] The 3GPP system shall support peak data rate up to [25] Mbps per UE for occasional transmissions.

[PR.5.3-004] The 3GPP system shall support efficient coordination of radio resources used for V2X communication to maximize the utilisation of the available spectrum and to ensure the required reliability.

[PR.5.3-005] The 3GPP system shall support high connection density for congested traffic.

NOTE: An example of estimate is for worst case US Freeway scenario that does not include arterial roads (i.e. onramps): 5 lanes in each direction or 10 lanes total per highway, for up to 3 highways intersecting = around 3,100 – 4,300 cars per square kilometer.

## 5.4 eV2X support for remote driving

### 5.4.1 Description

Remote driving is a concept in which a vehicle is controlled remotely by either a human operator or cloud computing.

While autonomous driving needs a lot of sensors and sophisticated algorithm like object identification, remote driving with human operators can be realized using less of them. For example, if on-board camera of the vehicle feeds the live video to remote human operator, human operator can easily understand the potential hazard of the vehicle without assistance of any sophisticated computing. Based on this video, the remote operator sends commands to the vehicle.

Remote driving can different use case than autonomous driving. Buses follow pre-defined static routes and a specific lane, and stop at pre-defined bus-stops. Thus, the characteristic of operating these buses are somewhat different from what is required for operating autonomous vehicles. For these buses, live video stream includes not only outside-bus image but also inside-bus image, so remote operators additionally need to react to more diverse scenario such as passengers getting on/off the bus.

Also, when cloud computing replaces human operators, coordination between vehicles can be achieved. For example, if all the vehicles feed their schedule and destination, the cloud can coordinate which route each vehicle will take. This coordination will reduce potential traffic congestion, overall travel time, leading to better fuel efficiency.

### 5.4.2 Potential requirements

The following potential requirements are derived from this use case:

[PR.5.4-001] The 3GPP system shall support user experienced data rate up to 1 Mbps at DL and 20 Mbps at UL for UE supporting V2X application for an absolute speed of up to 250 km/h.

NOTE: The assumption is that H.265/ HEVC HD stream is up to 10 Mb/s and two video streams are delivered to a remote driver.

[PR.5.4-002] The 3GPP system shall be able to control the UL and DL reliability of V2X communication, depending on the requirement of V2X application.

[PR.5.4-003] The 3GPP system shall support ultra-high UL and DL reliability (99.999 % or higher) for UE supporting safety-related V2X application for an absolute speed of up to 250 km/h.

[PR.5.4-004] The 3GPP system shall support end-to-end latency 5 ms between V2X application server and UE supporting safety-related V2X application for an absolute speed of up to 250 km/h.

## 5.5 Automated cooperative driving for short distance grouping

### 5.5.1 Description

#### 5.5.1.1 General

Cooperative driving allows a group of vehicles to automatically communicate to enable lane changing, merging, and passing between vehicles of the group and inclusion/removal of vehicle in the group in order to improved safety and fuel economy.

This use case is pushed by automotive industry because the reduced aerodynamic drag would result in greater fuel economy and a reduction in greenhouse gas emission. For all vehicle classes, close following from vehicle-to-vehicle communication and coordination allow more efficient use of the roadway, alleviating congestion and enhancing safety. It is foreseen, that the gap between vehicles will become much smaller, exceeding the response capability of the driver while improving the consumption of gasoline and improving the utilisation of the roads even more.

Automated Cooperative Driving requires far more automation than Cooperative Adaptive Cruise Control (CACC) described in Rel-14 V2X. CACC provides longitudinal control of vehicle motions, while the driver remains responsible for the steering control. CACC is an instantiation of Level 1 automation on both the SAE (Society of Automotive Engineers) [38] and NHTSA (The National Highway Traffic Safety Administration) scales [39] of automated driving; alternately, it is called "Assisted Driving" by BASt.(German Federal Highway Research Institute) and similarly, "Driver Assistance" by SAE. Automated Cooperative Driving provides ‘tighter’ or lower latency longitudinal control to enable a leader to communicates and coordinates with a group of vehicles, which enables close following. Moreover, Automated Cooperative Driving may in add lateral control, or higher levels of automation. The Automated Cooperative Driving conceptual framework allows innovative use of communications access in solving complex road traffic scenarios without driver intervention. Automated Cooperative Driving therefore enables SAE Level 2 through 5 automation ([10], [38])

The Basic Safety Message broadcast and similar uses of the Cooperative Awareness Message for V2V safety generally allow a nominal 100 ms latency, since the control loop to alert humans is long. Additionally, the V2V safety warning applications allow for reliability (PER) as low as 20 %. ([33])

In contrast, Automated Cooperative Driving requires:

- Very much lower latency for message exchange

- Higher reliability of message exchange: communication links must operate extremely reliably to mitigate risk of vehicular crashes.

- Higher density of transmitting UEs

- Larger messages exchanged

Cooperative Short Distance Grouping (CoSdG) refers to the scenario where the distance between vehicles such as trucks are extremely small – creating a desirable form of legal tailgating. The gap distance translated to time can equivalently be as low as 0.3s or even shorter, which at 80km/h leads to almost 6.7m distance between the vehicles [10]. Driving such closely is made possible by advanced automated cooperative driving technology, in combination with a highly reliable wireless vehicle-to-vehicle communication system that enables data transmission with low latency.

CoSdG is different than current platooning implementations summarized in [12], where ITS-G5 has been successfully used at a wide range of transmission rates (10 – 50 Hz). CoSdG envisions closer spacings and lower latency that what can reliably accomplished with alternative technologies. CoSdG would therefore enable a marked improvement in string stability, efficiency, and ultimately safety.

- Reliable wireless communications are required among the vehicles in a cooperative group. Messages are exchanged between the leading vehicles and all cooperating vehicles in order to execute control actions at the same time. CoSdG may not only be operated by vehicle-to-vehicle communication, but may also be vehicle-to-infrastructure and vehicle-to-backend communication to ensure most efficient utilisation of available resources and the required reliability.

- CoSdG may be used together with video transmission as explained in [9]. A display panel in any vehicles share forward-facing data, while drivers of the other cooperatively communicating group are able to display the video gathered by the camera mounted on other vehicles.

- CoSdG enables direct control intervention in mission critical scenarios. Information loss might lead to vehicle crashes. Messages must be transmitted reliably and delivered with very low latency. The jitter must be extremely low, as the electronic control unit operates usually on data provided periodically. Multiple vehicles must be linked to the leading vehicle by the wireless connection. When considering the mix of vehicles on the road, the number of vehicles can exceed 10,000 vehicles in scenarios with multiple lanes and multiple levels and types of roads.

There would be two phases for CoSdG:

- In Phase I, a baseline is proposed with a group of vehicles driving together with a lead vehicle are driven normally by a trained professional driver, and several following vehicles driven fully automatically by the system with information exchanged between the leader and other cars allowing with small distance (longitudinal gaps) between them. The typical required transmission frequency among the vehicles is up to 40Hz, [11], translating into 25ms end-to-end latency. Initial consideration of message exchange between vehicles in a platooning is based on CAM extension, which is around 300-400 bytes [11].

- In Phase II, all vehicles, the lead vehicle as well as following vehicles are driven fully automatically by the system. This will, compared to Phase I, allow smaller distance (longitudinal gaps) between them, leading to further reduction of fuel consumption. This requires in Phase II a higher transmission frequency compared to Phase I. The transmission frequency is 100Hz to coordinate the driving manoeuvre. The end-to-end latency is 1ms [13]

In addition, high precision positioning techniques should be supported by the mobile network to ensure the V2X information can be used even when GPS is not available, e.g. in very dense urban scenarios.

#### 5.5.1.2 Pre-conditions

1. Vehicles A, B & C are V2V enabled

2. Vehicle A, B & C are traveling in close proximity and in V2V communication range

3. Vehicle A is traveling outside of a group and wants to join the group which includes Vehicles B & C.

#### 5.5.1.3 Service flows

1. Vehicle B and other group members (e. g. C) share a message with the group information (i.e. size, speed, gap policies, their positions in the group, planned trajectory, etc.).

2. Vehicle A receives messages from the group members and identifies acceptable groups based on certain criteria (i.e. speed and gap policies, size).

3. Vehicle A sends a message to members of the group requesting to join group.

4. Vehicle B decides that Vehicle A or C can join the group ahead of it and responds with a confirmation and provides a gap (if necessary).

5. All other members of the group receive messages from Vehicle A and update the group information.

6. Vehicle A, B & C are traveling in close proximity

7. Vehicle A, B & C continuously exchange their on-board information, which when shared constitutes actual group information. This enables keep the optimal distance between all of the group members and to ensure safety. Each vehicle sends a state information V2X message to the vehicle right behind it.

8. Subsequently, the driver of Vehicle A decides to leave the group and assumes control of Vehicle A.

9. Vehicle A broadcasts a message indicating it will leave group to other members of the group.

10. Vehicle B receives the message from Vehicle A and updates the group information

#### 5.5.1.4 Post-conditions

1. Vehicle A leaves the group

2. Distance between vehicles has to be corrected based on updated group information

### 5.5.2 Potential requirements

All requirements are for end to end performance, defined as communications sent by source and communication received by target.

[PR-5.5-003a] The 3GPP system shall support less than 5 ms communication latency for transport of messages between two UEs supporting V2V applications, that are part of a group of UEs supporting V2V applications.

NOTE: The determination of group membership may be done at the upper layers and/or lower layers (application and/or Layer 2).

The 3GPP system shall support 1st set of KPIs in Phase I:

[PR.5.5-001] The 3GPP system shall support communication latency for data packets 300-400 bytes no larger than 25 ms.

[PR.5.5-002] The 3GPP system shall support over 90 % target packet delivery reliability rate.

[PR.5.5-003] The 3GPP system shall support triggered and periodic transmission of data packets 300-400 bytes.

The 3GPP system shall support 2nd set of KPIs in Phase II:

[PR.5.5-004] The 3GPP system shall support less than 10 ms communication latency for transport of V2X messages between two UEs supporting V2X application in proximity guaranteed in highly loaded network.

[PR.5.5-005] The 3GPP system shall support over [99.99] % target packet delivery reliability rate within 80 m range.

[PR.5.5-006] The 3GPP system shall support transmission of one data packet up to 1200 bytes every 25 ms within 80 m range.

[PR.5.5-007] The 3GPP system shall support relative lateral position accuracy of 0.1 m.

[PR.5.5-008] The 3GPP system shall support relative longitudinal position accuracy of less than 0.5 m for UEs supporting V2X application in proximity.

[PR.5.5-009] The 3GPP system shall support to ensure sufficient reliability metrics are reached.

[PR.5.5-010] The 3GPP system shall support high connection density for congested traffic.

Note: An example of estimate is for worst case US Freeway scenario that does not include arterial roads (i.e. onramps): 5 lanes in each direction or 10 lanes total per highway, for up to 3 highways intersecting = around 3,100 – 4,300 cars per mile.

## 5.6 Collective perception of environment

### 5.6.1 Description

#### 5.6.1.1 General

Vehicles can exchange real time information (based on vehicle sensors information or sensor data from a capable UE-type RSU) among each other in the neighbour area. This kind of information exchange leads to Collective Perception of Environment (CPE), which can enhance the perception of environment of vehicles to avoid accidents [15].

9.840 cars are considered per kilometre in the scenario with high vehicle density related to congested traffic road on US Freeway with 5 lanes in each direction (or 10 lanes total per highway), and up to 3 highways intersecting.

The information exchange has following characteristics:

- The information traffic should at least consist of 1600 payload byte to enable transmission of information related to 10 detected objects in order to support information from local environment perception and the information related to the actual vehicle status [16].

- The information shall be able to track changes in the environment by many other cars, with repetition rate of at least 5-10 Hz [16]. The update rate is chosen high enough such that the vehicle velocity vector does not change too much between updates. The information generated by each vehicle has to be delivered to all the neighbouring vehicles within the specified range (urban 50 m, rural 500 m, highway 1000m) [16].

Both traffic types (periodic and event driven) can exist at the same time.

There will be two Phases in Collective Perception of Environment (CPE), we can have two sets of KPIs for the two Phases, 1st Set of KPIs for Phase I and 2nd Set of KPIs for Phase II:

- Phase I: CPE addresses the use case where road users not able to periodically transmit messages for ITS services are detected and classified by other road users already equipped with 3GPP technology for ITS. These road users periodically transmit the information like object classification, speed, direction etc. detected with the local sensors. The pre-processed sensor information is used to enhance the environment perception with the overall goal to increase the benefit from 3GPP technology for ITS even in a not fully developed market. Requirements on 3GPP [15]: Packet size 1600 byte, end-to-end latency 100ms, 99% reliability [16].

- Phase II: CPE lays down the baseline for a set of cooperative automated driving use cases (e.g. automated forward collision avoidance, overtaking and lane changing) [14]. Phase II goes beyond road users’ detection and classification [15], the aim is to achieve an all-around view [14]. Sensor data information is shared to increase the limited sensor horizon to detect objects and obstacles in areas not visible to the local sensors e.g. behind crests, curves or objects behind the corner of houses [14]. These sensor data are used to control the vehicle without the human driver. Sensor data must be sent either in low resolution as pre-processed data or high resolution as raw data dependant on the scenario. Raw data are needed for liability reasons in case of accidents, for distributed verification of local and remote sensor data, furthermore to achieve accurate map merging as well as object localization [14]. Mobile communication performance significantly impacts the accurate environment modelling [15]. Requirements on 3GPP: Pre-processed data 50Mb/s, raw data 1Gb/s [17], [18], packet size 1600 byte, end-to-end latency 3ms [14] [17], reliability (emergency 99.999%) [5], otherwise 99.99% [19].

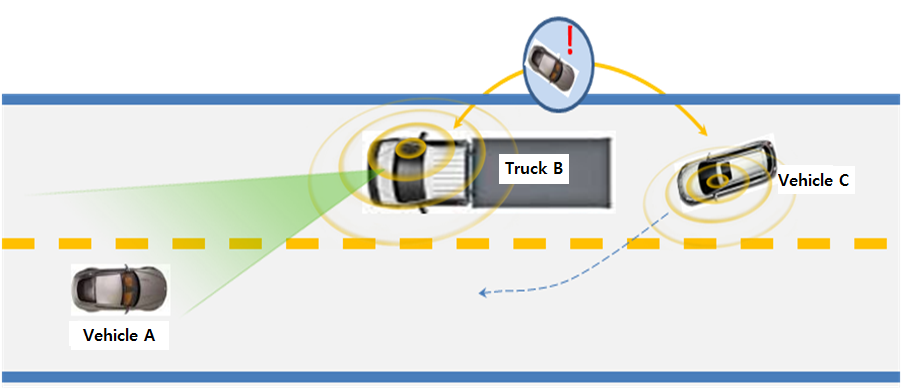


Figure 5.6.1.1-1: Collective Perception of Environment

#### 5.6.1.2 Pre-conditions

1. Vehicle A is not V2X enabled, Truck B and Vehicles C are V2X enabled.

2. Vehicle C is following the Truck B on the lane from east to west. Vehicle A is travelling on the lane from west to east, on the opposite direction of Truck B and Vehicle C.

3. Vehicle A, B & C are travelling in close proximity and in V2V communication range.

4. Vehicle C wants to overtake the Truck B.

#### 5.6.1.3 Service flows

1. At the beginning of the overtake manoeuvre, the Vehicle C is not able to perceive the Vehicle A.

2. Truck B detects the Vehicle A with its head sensor system and sends this environmental information via V2X Communication to Vehicle C.

3. The overtaking Vehicle C analyses the received information and gives the driver a warning of the danger.

4. The driver interrupts his overtaking manoeuvre because of the warning.

#### 5.6.1.4 Post-conditions

1. The potential accident has been avoided.

2. Vehicle C tries overtaking again later when the vehicle A is travelling through and the next information shared by the Truck B shows that the traffic is safe.

### 5.6.2 Potential requirements

The 3GPP system shall support 1st set of KPIs in Phase I:

[PR.5.6-001] The 3GPP system shall be able to support [100] ms end-to-end latency for message transfer among a group of UEs supporting V2X application.

[PR.5.6-002] The 3GPP system shall be able to support over [99] % target packet delivery reliability rate in [1000] m.

[PR.5.6-003] The 3GPP system shall be able to support periodic transmission of data packets (e.g. [1600] bytes).

The 3GPP system shall support 2nd set of KPIs in Phase II:

[PR.5.6-004] The 3GPP system shall be able to support [3] ms end-to-end latency and [99.999] % reliability for message transfer among a group of UEs supporting V2X application within [200] m communication range.

[PR.5.6-005] The 3GPP system shall be able to support [10] ms end-to-end latency and [99.99] % reliability for message transfer among a group of UEs supporting V2X application within [500] m communication range.

[PR.5.6-006] The 3GPP system shall be able to support [50] ms end-to-end latency and [99] % reliability for message transfer among a group of UEs supporting V2X application within [1000] m communication range.

[PR.5.6-007] The 3GPP system shall be able to support peak data rate of [1] Gbps for a single UE for a short period of time in range of [50] m, in case of imminent collision.

NOTE: Only one of the requirements [PR.5.6-004], [PR.5.6-005], [PR.5.6-006], and/or [PR.5.6-007] need to be fulfilled at the same time.

## 5.7 Communication between vehicles of different 3GPP RATs

### 5.7.1 Description

Depending on the choice of OEMs, while some vehicles are equipped with modules supporting only LTE, other vehicles may be equipped with modules supporting NR (New Radio). If a vehicle of NR cannot talk to a vehicle supporting LTE, the vehicle supporting LTE can be regarded as another vehicle of no V2X capability.

The following figure 5.7.1-1 shows the scenarios to be considered.



Figure 5.7.1-1: Example scenario of mixed 3GPP RATs deployment

No coverage

In this area, neither E-UTRAN nor NR access network is found. Because there is no network support for the communication among vehicles, direct Prose communication based on LTE and/or NR is the only option available for the communication between the vehicles.

For communication toward other NR-based vehicle, it seems straight-forward for a NR-based vehicle to use direct Prose communication based on NR. Performance of NR-based direct Prose communication will surpass that of LTE-based direct Prose communication.

However, considering that the average lifespan of the vehicles is longer than 10 years, it is likely that LTE-based vehicle exists near the NR-based vehicle. Because LTE-based vehicle cannot understand NR-based Prose direct communication, one choice is that the NR-based vehicle can communicate with the LTE-based vehicle using LTE-based communication. With thisdirect communication between vehicles can be supported.

By the way, this does not necessarily mean that enhancement in NR-based Prose direct communication is limited to what LTE-based Prose direct communication can provide. For the basic safety service, LTE compatible Prose direct communication is used and NR-optimized direct communication can be used for advanced V2X service such as platooning.

LTE only coverage

Because there is no NR-based Access Network, NR-based vehicle is not provided with any network support and the only choice for the NR-based vehicle is to use Prose direct communication.

On the other hand, within LTE coverage, LTE-based vehicle can be controlled by the network, i.e. whether to use LTE-based direct communication or not. Based on the network’s decision, V2X-related traffic generated by LTE-based vehicle can be routed through the V2X application server. In this case, LTE-based vehicle does not use direct Prose communication and the direct communication between NR-based vehicle and LTE-based vehicle is not possible.

However, in this area, if a NR-based vehicle behaves in a same way as in the area of no LTE/NR coverage, the transmission from the NR-based vehicle may generate interference to E-UTRAN. Thus, impact to E-UTRAN can be minimized by NR-based vehicle.

LTE/NR coverage

Because both LTE-based vehicle and NR-based vehicle are within coverage of networks, communication between the vehicles are possible indirectly via the network, regardless of whether the vehicles can use direct Prose communication or not, or whether they use same radio access technology or not.

### 5.7.2 Potential requirements

The following potential requirements are derived from this use case:

[PR.5.7-001] Void

[PR.5.7-002] Impact to E-UTRA(N) by UE supporting only 5G RAT(s) based V2X communication shall be minimized.

[PR.5.7-003] Impact to 5G RA(N) by UE supporting only E-UTRA based V2X communication shall be minimized.

## 5.8 Multi-PLMN environment

### 5.8.1 Description

#### 5.8.1.1 General

Although required communication condition, e.g. for immediate message transfer, is set high for some of eV2X use cases, such condition needs to be met regardless of whether or not all the involved UEs and UE-type RSUs are subscriber of the same PLMN.

#### 5.8.1.2 Pre-conditions

1. Vehicles A and B and UE-type RSU X are subscriber of PLMN P. Vehicle C is subscriber of PLMN Q.

2. A, B, C and X support V2X communication.

3. Any combination of A, B, and X are in communication range.

#### 5.8.1.3 Service flows

1. C comes into the communication range of A, B, and X.

2. Each vehicle shares its detected objects and/or coarse driving intention with other vehicles. Each UE-type RSU shares its detected objects with vehicles. Each vehicle obtains the information of surrounding objects that cannot be obtained only from local sensors and also obtains the driving intention of the other vehicles in proximity.

3. A recognizes no service degradation of the message transfer between with B and with C.

#### 5.8.1.4 Post-conditions

1. Each vehicle utilizes the received information of detected objects and/or coarse driving intention of other vehicles as predictive information for its driving.

2. Road safety and traffic efficiency is improved. Having C does not degrade that.

### 5.8.2 Potential requirements

[PR.5.8-001] The 3GPP system shall be able to support message transfer between UEs or between a UE and a UE-type RSU, regardless of whether or not they are subscribers of the same PLMN supporting V2X communications. In case they are subscribers to different PLMNs, there shall be no service degradation of the message transfer.

## 5.9 Cooperative collision avoidance (CoCA) of connected automated vehicles

### 5.9.1 Description

#### 5.9.1.1 General

To enable vehicles to better evaluate the probability of an accident and to coordinate manoeuvres in addition to usual CAM, DENM safety messages, data from sensors, list of actions like braking and accelerating commands, lateral as well as longitudinal control are exchanged amongst vehicles to coordinate in the application the road traffic flow through 3GPP V2X communication.

Key Performance Indicators (KPIs):

- Throughput of 10 Mbps [36] to exchange CoCA application messages between UEs in proximity to perform coordinated driving manoeuvre at intersections.

- Message size up to 2 kByte [37] depending on the number of involved vehicles, to exchange pre-planned trajectories between vehicles.

- Less than 10 ms [2] latency for regular manoeuvre coordination within the CoCA application time limit.

- 99.99 % [2] reliability for safety coordinated driving manoeuvre.

#### 5.9.1.2 Pre-conditions

- Vehicles A, B, C support message exchange via 3GPP V2X communication.

- Vehicles A, B, C support basis for V2X safety application (CAM, DENM etc.) so they already know their relative positions.

- With relative positions, Vehicles A, B, C are able to operate CoCA application.

#### 5.9.1.3 Service flows

- Vehicle A, B or C detects the risk of collision.

- V2X application of vehicle A detects a risk of collision. Vehicle A's application exchanges CoCA related messages (trajectories, sensor data, brake commands etc.) via 3GPP V2X communication service.

- Vehicles B and C confirm on application layer to vehicle A the coordinated manoeuvre for CoCA by transmitting messages via 3GPP communication service.

#### 5.9.1.4 Post-conditions

- Vehicles A, B and C perform coordinated manoeuvre.

### 5.9.2 Potential requirements

[PR.5.9-001] The 3GPP network shall enable communication between UEs to support message exchange with [10] Mbps data throughput with less than [10] ms latency.

[PR.5.9-002] The 3GPP network shall enable UE’s message exchange with [99.99] % reliability and message sizes in range up to [2] kByte.

## 5.10 Information sharing for partial/ conditional automated driving

### 5.10.1 Description

#### 5.10.1.1 General

This use case is interpreted as an automated driving at the level of e.g. SAE Level 3 automation and SAE Level 2 automation [38], where non-short inter-vehicle distance (e.g. >2sec \* vehicle speed) is assumed and abstracted/coarse data exchange is sufficient.

The following applies for aspects of cooperative perception and cooperative manoeuvre.

NOTE 1: Cooperative perception is defined in general as sharing local perception data (abstracted data and/or high resolution sensor data) using V2X communication to expand detectable range of on-board sensor capability. Here, each vehicle and/or RSU shares its own perception data obtained from its local sensors (e.g., camera, LIDAR, radar, etc.), with vehicles in proximity.

NOTE 2: Cooperative manoeuvre is defined in general as sharing driving intention information (coarse and/or high resolution) using V2X communication for cooperative manoeuvre. Here, each vehicle shares its driving intention with vehicles in proximity.

- Cooperative perception: This use case requires sharing detected objects (e.g., abstracted object information detected by local sensors) among vehicles in the same area.

- Cooperative manoeuvre: This use case requires sharing coarse driving intention (e.g., changing lanes or moving/ stopping/ parking in T sec at [x,y,z]) for changing lanes, merging at highway and roundabout, crossing at 4-way stop and have consensus among all involved vehicles via V2X.

The following requirements apply for KPIs.

- Data rate: [0.5] Mbps per link for cooperative perception. [0.05] Mbps per link for cooperative manoeuvre.

NOTE 3: [0.5] Mbps is derived from: 60 byte/object, 100 objects, [10] messages/sec. [0.05] Mbps is derived from: few 100 bytes (e.g., 500 byte) /message, [10] messages/sec. (cf. [20]) The message transmission rate [10] messages/sec comes from assumption that a transmitter vehicle and RSU generate a new message every [100] ms. (cf. [22])

NOTE 4: Broadcast or multicast, periodic (or event-triggered) is assumed.

- End-to-end latency: low

NOTE 5: Low application-layer end-to-end latency is required (e.g. [100] ms) (cf. [20]).

- Reliability: High reliability

- Communication range: [10] sec \* (maximum relative speed [m/s]) (cf. [21])

NOTE 6: In SAE Level 3 automation [38], the driver is expected to be available for taking full control when the automated driving system is no longer able to support automation, with sufficiently comfortable transition time (e.g., [10] sec). To this end, the vehicle needs to obtain predictive information of environments sufficient ahead. (cf. [23])

NOTE 8: In general, between UEs, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-100] km/h, Sub-urban: [0-200] km/h, Autobahn: [0-250] km/h (same direction). Between UE and RSU, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-50] km/h, Sub-urban: [0-100] km/h, Autobahn: [0-250] km/h (same direction). (cf. [2])

- Density of connection devices: High density

#### 5.10.1.2 Pre-conditions

1. Vehicles A, B, and C and RSUs X, Y, and Z support V2X communication for information sharing for limited automated driving.

2. Any combination of vehicles A, B, and C and RSUs X, Y, and Z are in communication range.

3. Vehicles A, B, and C are travelling in proximity, where inter-vehicle distance is not short (e.g. >2sec \* vehicle speed).

#### 5.10.1.3 Service flows

1. Each vehicle shares its detected objects (e.g., abstracted object information detected by local sensors) and/or coarse driving intention with other vehicles. Each RSU shares its detected objects with vehicles A, B, and C.

2. Each vehicle obtains the information of surrounding objects that cannot be obtained only from local sensors and also obtains the driving intention of the other vehicles in proximity.

#### 5.10.1.4 Post-conditions

1. Each vehicle utilizes the received information of detected objects and/or coarse driving intention of other vehicles as predictive information for its driving.

2. Road safety and traffic efficiency is improved.

### 5.10.2 Potential requirements

[PR.5.10-001] The 3GPP system shall be capable of supporting user experienced data rate of [0.55] Mbps between UEs supporting V2X application.

[PR.5.10-002] The 3GPP system shall be capable of supporting user experienced data rate of [0.5] Mbps between a UE supporting V2X application and an RSU.

[PR.5.10-003] The 3GPP system shall be capable of transferring periodic broadcast/multicast messages between two UEs supporting V2X application with message payloads of [6500] bytes, not including security-related message component.

[PR.5.10-004] The 3GPP system shall be capable of transferring periodic broadcast/multicast messages between a UE supporting V2X application and an RSU with message payloads of [6000] bytes, not including security-related message component.

[PR.5.10-005] The 3GPP system shall be capable of supporting a maximum frequency of [10] messages per second per transmitting UE.

[PR.5.10-006] The 3GPP system shall be capable of transferring messages between two UEs supporting V2X application, directly or via an RSU, with a maximum application-layer end-to-end latency of [100] ms.

[PR.5.10-007] The 3GPP system shall be capable of transferring messages between a UE supporting V2X application and an RSU with a maximum application-layer end-to-end latency of [100] ms.

[PR.5.10-008] The 3GPP system shall be capable of supporting high reliability without requiring application-layer message retransmissions.

[PR.5.10-009] The 3GPP system shall be capable of supporting a communication range sufficient to give the predictive information to the vehicles in proximity (e.g. [10] sec \* (maximum relative speed) [m/s]).

NOTE: In each mobility scenario, [10] sec \* (maximum relative speed) [m/s] is equal to: [278] m for the maximum relative speed of [100] km/h in urban, [556] m for the maximum relative speed of [200] km/h in sub-urban, and [694] m for the maximum relative speed of [250] km/h in Autobahn (same direction).

[PR.5.10-010] The 3GPP system shall be capable of supporting a high connection density.

## 5.11 Information sharing for high/full automated driving

### 5.11.1 Description

#### 5.11.1.1 General

This use case is interpreted as an automated driving at the level of e.g. SAE Level 4 and Level 5 automation [38], where non-short inter-vehicle distance (e.g. >2sec \* vehicle speed) is assumed and high-resolution data exchange is required.

The following applies for aspects of cooperative perception and cooperative manoeuvre.

- Cooperative perception: This use case requires sharing high resolution perception data (e.g., camera, LIDAR, occupancy grid) among vehicles in the same area.

- Cooperative manoeuvre: This use case requires sharing detailed planned trajectory among all involved vehicles via V2X for collaborative manoeuvre.

The following requirements apply for KPIs.

- Data rate: [50] Mbps per link for cooperative perception. [3] Mbps per link for cooperative manoeuvre.

NOTE 1: [50] Mbps is derived from: H.265/ HEVC HD camera ~10 Mbps + LIDAR ~35 Mbps (6 vertical angles, 64 elements, [10] Hz horizontal rotation) + other sensor data. [3] Mbps is derived from: Planned trajectory ~2.5 Mbps (32 byte/coordinate, 10 ms resolution, 10 sec trajectory, [10] messages/sec) + other intention data. (cf. [20]) The message transmission rate of [10] messages/sec for the purpose of calculation comes from assumption that a transmitter vehicle and RSU generate a new message every [100] ms. (cf. [22])

- End-to-end latency: low

NOTE 2: Low application-layer end-to-end latency is required (e.g. [100] ms) (cf. [20]).

- Reliability: High reliability

- Communication range: [5] sec \* (maximum relative speed [m/s]) (cf. [21])

NOTE 3: In SAE Level 4 and Level 5 automation (cf. [23] [38]), the automated driving system is expected to be available for control without human intervention. To this end, the vehicle needs to obtain predictive information of environments sufficient ahead (e.g., [5] sec ahead). (cf. [24])

NOTE 4: In general, between UEs, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-100] km/h, Sub-urban: [0-200] km/h, Autobahn: [0-250] km/h (same direction). Between UE and RSU, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-50] km/h, Sub-urban: [0-100] km/h, Autobahn: [0-250] km/h (same direction). (cf. [2])

- Density of connection devices: High density

#### 5.11.1.2 Pre-conditions

1. Vehicles A, B, and C and RSUs X, Y, and Z support V2X communication for information sharing for full automated driving.

2. Any combination of vehicles A, B, and C and RSUs X, Y, and Z are in communication range.

3. Vehicles A, B, and C are travelling in proximity, where inter-vehicle distance is not short (e.g. >2 sec \* vehicle speed).

#### 5.11.1.3 Service flows

1. Each vehicle shares its high resolution perception data (e.g., camera, LIDAR, occupancy grid) and/or detailed planned trajectory with other vehicles. Each RSU shares its high resolution perception data with vehicles A, B, and C.

2. Each vehicle obtains the information of the surrounding environment that cannot be obtained only from local sensors and also obtains the planned trajectory of the other vehicles in proximity.

#### 5.11.1.4 Post-conditions

1. Each vehicle utilizes the received information of high resolution perception data and/or planned trajectory of other vehicles as predictive information for its driving.

2. Road safety and traffic efficiency is improved.

### 5.11.2 Potential requirements

[PR.5.11-001] The 3GPP system shall be capable of supporting user experienced data rate of [53] Mbps between UEs supporting V2X application.

[PR.5.11-002] The 3GPP system shall be capable of supporting user experienced data rate of [50] Mbps between a UE supporting V2X application and an RSU.

[PR.5.11-003] The 3GPP system shall be capable of transferring messages between two UEs supporting V2X application, directly or via an RSU, with a maximum application-layer end-to-end latency of [100] ms.

[PR.5.11-004] The 3GPP system shall be capable of transferring messages between a UE supporting V2X application and an RSU with a maximum application-layer end-to-end latency of [100] ms.

[PR.5.11-005] The 3GPP system shall be capable of supporting high reliability without requiring application-layer message retransmissions.

[PR.5.11-006] The 3GPP system shall be capable of supporting a communication range sufficient to give the predictive information to the vehicles in proximity (e.g. [5] sec \* (maximum relative speed) [m/s]).

NOTE: In each mobility scenario, [5] sec \* (maximum relative speed) [m/s] is equal to: [139] m for the maximum relative speed of [100] km/h in urban, [278] m for the maximum relative speed of [200] km/h in sub-urban, and [347] m for the maximum relative speed of [250] km/h in Autobahn (same direction).

[PR.5.11-007] The 3GPP system shall be capable of supporting a high connection density.

## 5.12 Information sharing for partial/ conditional automated platooning

### 5.12.1 Description

#### 5.12.1.1 General

This use case is interpreted as an automated platooning at the level of e.g. SAE Level 3 automation [38], where short inter-vehicle distance (e.g. <2sec \* vehicle speed) is assumed and abstracted/coarse data exchange is sufficient.

The following applies for aspects of cooperative perception and cooperative manoeuvre.

NOTE 1: Cooperative perception is defined in general as sharing local perception data (abstracted data and/or high resolution sensor data) using V2X communication to expand detectable range of on-board sensor capability. Here, each vehicle and/or RSU shares its own perception data obtained from its local sensors (e.g., camera, LIDAR, radar, etc.), with vehicles in proximity.

NOTE 2: Cooperative manoeuvre is defined in general as sharing driving intention information (coarse and/or high resolution) using V2X communication for cooperative manoeuvre. Here, each vehicle shares its driving intention with vehicles in proximity.

- Cooperative perception: This use case requires sharing detected objects (e.g., abstracted object information detected by local sensors) among vehicles in the same area.

- Cooperative manoeuvre: This use case requires sharing coarse driving intention (e.g., changing lanes or moving/ stopping/ parking in T sec at [x,y,z]) for changing lanes, merging at highway and roundabout, crossing at 4-way stop and have consensus among all involved vehicles via V2X.

The following requirements apply for KPIs.

- Data rate: [2.5] Mbps per link for cooperative perception. [0.25] Mbps per link for cooperative manoeuvre.

NOTE 3: [2.5] Mbps is derived from: 60 byte/object, 100 objects, [50] messages/sec. [0.25] Mbps is derived from: few 100 bytes (e.g., 500 byte) / message, [50] messages/sec. (cf. [20]) The message transmission rate [50] messages/sec comes from assumption that a transmitter vehicle and RSU generate a new message every [20] ms. (cf. [22])

NOTE 4: Broadcast or multicast, periodic (or event-triggered) is assumed.

- End-to-end latency: low

NOTE 5: Low application-layer end-to-end latency is required (e.g. [20] ms) (cf. [20]).

- Reliability: High reliability

- Communication range: [10] sec \* (maximum relative speed [m/s]) (cf. [21])

NOTE 6: In SAE Level 3 automation [38], the driver is expected to be available for taking full control when the automated driving system is no longer able to support automation, with sufficiently comfortable transition time (e.g., [10] sec). To this end, the vehicle needs to obtain predictive information of environments sufficient ahead. (cf. [23])

NOTE 8: In general, between UEs, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-100] km/h, Sub-urban: [0-200] km/h, Autobahn: [0-250] km/h (same direction). Between UE and RSU, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-50km/h], Sub-urban: [0-100] km/h, Autobahn: [0-250] km/h (same direction). (cf. [2])

- Density of connection devices: High density

#### 5.12.1.2 Pre-conditions

1. Vehicles A, B, C, D, E, and F and RSUs X, Y, and Z support V2X communication for information sharing for limited automated platooning.

2. Any combination of vehicles A, B, C, D, E, and F and RSUs X, Y, and Z are in communication range.

3. Vehicles A, B, and C are travelling as a platoon group ABC. In proximity to the platoon group ABC, vehicles D, E, and F are travelling as another platoon group DEF. For vehicles in the same platoon group, inter-vehicle distance is short (e.g. <2 sec \* vehicle speed).

#### 5.12.1.3 Service flows

1. Each vehicle shares its detected objects (e.g., abstracted object information detected by local sensors) and/or coarse driving intention with other vehicles (not only vehicles in the same platoon group but also vehicles in different platoon group in proximity). Each RSU shares its detected objects with vehicles A, B, C, D, E, and F.

2. Each vehicle obtains the information of surrounding objects that cannot be obtained only from local sensors and also obtains the driving intention of other vehicles in the same platoon and different platoon in proximity.

#### 5.12.1.4 Post-conditions

1. Each vehicle utilizes the received information of detected objects and/or coarse driving intention of other vehicles as predictive information for its platooning manoeuvre.

2. Road safety and traffic efficiency is improved.

### 5.12.2 Potential requirements

[PR.5.12-001] The 3GPP system shall be capable of supporting user experienced data rate of [2.75] Mbps between UEs supporting V2X application.

[PR.5.12-002] The 3GPP system shall be capable of supporting user experienced data rate of [2.5] Mbps between a UE supporting V2X application and an RSU.

[PR.5.12-003] The 3GPP system shall be capable of transferring periodic broadcast/multicast messages between two UEs supporting V2X application with message payloads of [6500] bytes, not including security-related message component.

[PR.5.12-004] The 3GPP system shall be capable of transferring periodic broadcast/multicast messages between a UE supporting V2X application and an RSU with message payloads of [6000] bytes, not including security-related message component.

[PR.5.12-005] The 3GPP system shall be capable of supporting a maximum frequency of [50] messages per second per transmitting UE.

[PR.5.12-006] The 3GPP system shall be capable of transferring messages between two UEs supporting V2X application, directly or via an RSU, with a maximum application-layer end-to-end latency of [20] ms.

[PR.5.12-007] The 3GPP system shall be capable of transferring messages between a UE supporting V2X application and an RSU with a maximum application-layer end-to-end latency of [20] ms.

[PR.5.12-008] The 3GPP system shall be capable of supporting high reliability without requiring application-layer message retransmissions.

[PR.5.12-009] The 3GPP system shall be capable of supporting a communication range sufficient to give the predictive information to the vehicles in proximity (e.g. [10] sec \* (maximum relative speed) [m/s]).

NOTE: In each mobility scenario, [10] sec \* (maximum relative speed) [m/s] is equal to: [278] m for the maximum relative speed of [100] km/h in urban, [556] m for the maximum relative speed of [200] km/h in sub-urban, and [694] m for the maximum relative speed of [250] km/h in Autobahn (same direction).

[PR.5.12-010] The 3GPP system shall be capable of supporting a high connection density.

## 5.13 Information sharing for high/full automated platooning

### 5.13.1 Description

#### 5.13.1.1 General

This use case is interpreted as an automated platooning at the level of e.g. SAE Level 4 and Level 5 automation [38], where short inter-vehicle distance (e.g. <2 sec \* vehicle speed) is assumed and high-resolution data exchange is required.

The following applies for aspects of cooperative perception and cooperative manoeuvre.

- Cooperative perception: This use case requires sharing high resolution perception data (e.g., camera, LIDAR, occupancy grid) among vehicles in the same area.

- Cooperative manoeuvre: This use case requires sharing detailed planned trajectory among all involved vehicles via V2X for collaborative manoeuvre.

The following requirements apply for KPIs.

- Data rate: [50] Mbps per link for cooperative perception. [15] Mbps per link for cooperative manoeuvre.

NOTE 1: For cooperative perception, it is to be considered if we need messages with higher data rate instead of the messages needed for full automated driving of [50] Mbps. [15] Mbps is derived from: Planned trajectory ~12.5 Mbps (32 byte/coordinate, 10 ms resolution, 10 sec trajectory, [50] messages/sec) + other intention data. (cf. [20]) The message transmission rate of [50] messages/sec for the purpose of calculation comes from assumption that a transmitter vehicle and RSU generate a new message every [20] ms. (cf. [22])

- End-to-end latency: low

NOTE 2: Low application-layer end-to-end latency is required (e.g. [20] ms) (cf. [20]).

- Reliability: High reliability

- Communication range: [5] sec \* (maximum relative speed [m/s]) (cf. [21])

NOTE 3: In SAE Level 4 and Level 5 automation (cf. [23] [38]), the automated driving system is expected to be available for control without human intervention. To this end, the vehicle needs to obtain predictive information of environments sufficient ahead (e.g., [5] sec ahead). (cf. [24])

NOTE 4: In general, between UEs, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-100] km/h, Sub-urban: [0-200] km/h, Autobahn: [0-250] km/h (same direction). Between UE and RSU, the following mobility [km/h] (Relative vehicle speed) is assumed: Urban: [0-50] km/h, Sub-urban: [0-100] km/h, Autobahn: [0-250] km/h (same direction). (cf. [2])

- Density of connection devices: High density

#### 5.13.1.2 Pre-conditions

1. Vehicles A, B, C, D, E, and F and RSUs X, Y, and Z support V2X communication for information sharing for full automated platooning.

2. Any combination of vehicles A, B, C, D, E, and F and RSUs X, Y, and Z are in communication range.

3. Vehicles A, B, and C are travelling as a platoon group ABC. In proximity to the platoon group ABC, vehicles D, E, and F are travelling as another platoon group DEF. For vehicles in the same platoon group, inter-vehicle distance is short (e.g. <2 sec \* vehicle speed).

#### 5.13.1.3 Service flows

1. Each vehicle shares its high resolution perception data (e.g., camera, LIDAR, occupancy grid) and/or detailed planned trajectory with other vehicles (not only vehicles in the same platoon group but also vehicles in different platoon group in proximity). Each RSU shares its high resolution perception data with vehicles A, B, C, D, E, and F.

2. Each vehicle obtains the information of the surrounding environment that cannot be obtained only from local sensors and also obtains the planned trajectory of other vehicles in the same platoon and different platoon in proximity.

#### 5.13.1.4 Post-conditions

1. Each vehicle utilizes the received information of high resolution perception data and/or planned trajectory of other vehicles as predictive information for its platooning manoeuvre.

2. Road safety and traffic efficiency is improved.

### 5.13.2 Potential requirements

[PR.5.13-001] The 3GPP system shall be capable of supporting user experienced data rate of [65] Mbps between UEs supporting V2X application.

[PR.5.13-002] The 3GPP system shall be capable of supporting user experienced data rate of [50] Mbps between a UE supporting V2X application and an RSU.

[PR.5.13-003] The 3GPP system shall be capable of transferring messages between two UEs supporting V2X application, directly or via an RSU, with a maximum application-layer end-to-end latency of [20] ms.

[PR.5.13-004] The 3GPP system shall be capable of transferring messages between a UE supporting V2X application and an RSU with a maximum application-layer end-to-end latency of [20] ms.

[PR.5.13-005] The 3GPP system shall be capable of supporting high reliability without requiring application-layer message retransmissions.

[PR.5.13-006] The 3GPP system shall be capable of supporting a communication range sufficient to give the predictive information to the vehicles in proximity (e.g. [5] sec \* (maximum relative speed) [m/s]).

NOTE: In each mobility scenario, [5] sec \* (maximum relative speed) [m/s] is equal to: [139] m for the maximum relative speed of [100] km/h in urban, [278] m for the maximum relative speed of [200] km/h in sub-urban, and [347] m for the maximum relative speed of [250] km/h in Autobahn (same direction).

[PR.5.13-007] The 3GPP system shall be capable of supporting a high connection density.

## 5.14 Dynamic ride sharing

### 5.14.1 Description

#### 5.14.1.1 General

This use case enables a vehicle to advertise willingness to share capacity with another road user and for a pedestrian to indicate intent to travel in a ride share. The vehicle may share information about itself such as current occupancy, available capacity, destination, estimated time of arrival, interstitial stops etc. The pedestrian may share information about itself such as destination, some personal information and credentials, etc.

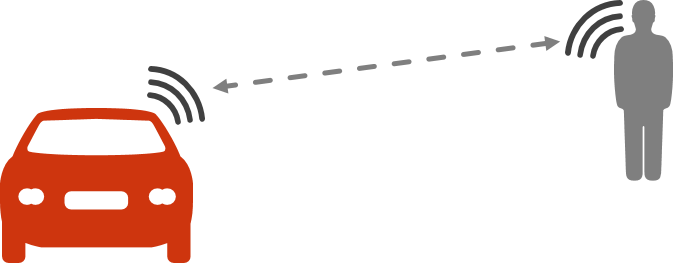


Figure 5.14.1.1-1: Dynamic ride sharing

Collaboratively the two actors can make a decision about suitability for ride sharing and present any positive findings to the pedestrian and/or driver. This scenario can be based on a vehicle being privately owned, pooled, private hire, taxi, public transport, campus transport, or other forms of ride sharing dynamic.

#### 5.14.1.2 Pre-conditions

Vehicle A and Pedestrian B are V2X enabled (with ProSe like capabilities, e.g. Discovery and/or Communication).

Vehicle A is heading towards certain direction, and decides to take up a rider with certain limitations e.g. going to certain area, time limit, etc. Vehicle A may be a taxi type of service, airport shuttle, or the driver may simply enjoy car pool driving or toll benefits.

#### 5.14.1.3 Service flows

1. Driver of Vehicle A decides to share the ride with another rider,

2. Vehicle A broadcast a message to indicate intention to find a passenger to share the ride, and destination, etc.

3. Pedestrian B intends to find a vehicle to go to the same destination

4. Pedestrian B’s mobile device broadcast a message to indicate its intention to find a vehicle for a destination

5. Vehicle A and Pedestrian B discovered each other by receiving the message, and starts to exchange information to set up the ride sharing details.

6. If the conditions expressed by both parties are satisfied, the ride share can be arranged and started.

#### 5.14.1.4 Post-conditions

Pedestrian B can ride share in vehicle A.

### 5.14.2 Potential requirements

[PR.5.14-001] A UE supporting a V2X application shall be able to discover other such UEs in proximity supporting the same application.

NOTE: Proximity can either be determined using direct radio signals or via the operator network

[PR.5.14-002] A UE supporting a V2X application shall be able to establish direct unicast communication with another such UE based on discovery results.

## 5.15 Use case on multi-RAT

### 5.15.1 Description

The user starts a V2X application, and a message from that application needs to be transmitted to other cars nearby. The V2X UE supports multiple radio access technologies (RATs), including LTE and 5G New RAT (NR). The V2X UE should choose the best technology to support the given application of interest.

The V2X UE chooses to transmit the message for a given application over the best RAT. The best RAT is selected based on information configured by the network (e.g., mapping between application ID and RAT or PSID/ITS AID and RAT) or QoS-related requirements provided by the application when establishing the service. Other factors may be taken into account during the RAT selection, such as number of V2X UEs using a given technology and presence of RSUs.

### 5.15.2 Potential requirements

[PR.5.15-001] The 3GPP network shall allow the operator to associate a V2X application to one or more 3GPP RATs in a UE supporting V2X application.

## 5.16 Video data sharing for assisted and improved automated driving (VaD)

### 5.16.1 Description

#### 5.16.1.1 General

The visual range of the driver is in some road traffic situations obstructed, for instance by trucks driving in front [26]. Video data sent from one vehicle to the other can support drivers in these safety-critical situations. Video data may also be collected and sent through a capable UE-type RSU.

But sharing pre-processed data, where objects are for instance extracted by an automatic object detection, is not sufficient, because the drivers’ decision on a manoeuvre is subject to their driving capability and safety preferences (distance between cars, velocity of vehicles in oncoming direction) [2].

Sharing high resolution video data better supports drivers to make the manoeuvre decision according to their safety preferences. However, sharing low resolution video data is not sufficient, as obstacles are not visible and might get overlooked. Additionally, video data compression needs to be avoided as it leads to higher delays [2].

The following two sets of Key Performance Indicators (KPIs) relate to different technology levels of driving automation.

KPIs for set 1 enables service to be considered by a human visual system (driver is still in the control loop, but it does not exclude being a machine):

- Latency less than 50 ms to enable near real-time video data sharing and monitoring on the application layer.

- Data rate 10 Mbps [2] to transmit at least progressive high definition video data with resolution 720p and 30 frames per second [2].

- Reliability 90 % to avoid massive artifacts in the video stream.

KPIs for set 2 relates to machine-centric video data analysis (e.g. for ultra-accurate position estimation etc.):

- Latency less than 10 ms to avoid additional buffer delays which will cause time- and space mismatch between shared video data.

- Data rate 100 – 700 Mbps for computer vision based on raw video data transmission [27] (e.g. six cameras with resolution 1280 x 720, 24 Bit per pixel, 30 fps) to rely on vendors’ specific classifiers [28].

- Reliability 99.99% [20] to avoid errors when applying algorithms for computer vision.

#### 5.16.1.2 Pre-conditions



Figure 5.16.1.2-1: Video data sharing for assisted and improved automated Driving (VaD)

- Vehicle A, B supports 3GPP V2X communication service.

- Vehicle A, B supports VaD application.

- Vehicle A and B are in communication range.

#### 5.16.1.3 Service flows

- Vehicle A announces VaD capability on the application layer through periodic application message exchange via 3GPP V2X communication service.

- Vehicle B requests VaD application information from Vehicle A from message transfer via 3GPP V2X communication service.

- Vehicle A transmits VaD application data periodically.

- Vehicle B transmits VaD application message releasing from Vehicle A after having overtaken vehicle B or vehicle A stops to transmit data after a while.

#### 5.16.1.4 Post-conditions

- Drivers are supported in rough terrains and aware of hazardous driving situations ahead.

### 5.16.2 Potential requirements

KPIs for set 1:

[PR.5.16-001] The 3GPP network shall enable communication between UEs with [10] Mbps data rate, less than [50] ms latency and [90] % reliability within a communication range of [100] m.

KPIs for set 2:

[PR.5.16-002] The 3GPP network shall enable communication with up to [700] Mbps data rate, less than [10] ms latency and [99.99] % reliability within communication range of [500] m.

## 5.17 Changing driving-mode

### 5.17.1 Description

#### 5.17.1.1 General

According to a vehicle cooperation level, driving-mode can be classified generally into three classes [2]. One is autonomous driving. Another is convoy. The other is platooning, where maximum platooning size can be up to 20 [29]. In spite of each driving-mode’s own advantage, however, there exist nontrival traffic scenarios which can result in traffic accidents when the present activated driving-mode is not switched into the other driving-mode. Here, changing driving-mode is activated by the following process.

1. The designated vehicle transmits a kind of request message regarding changing driving-mode.

2. Each vehicle in a group sends a kind of response message corresponding the driving-mode change request.

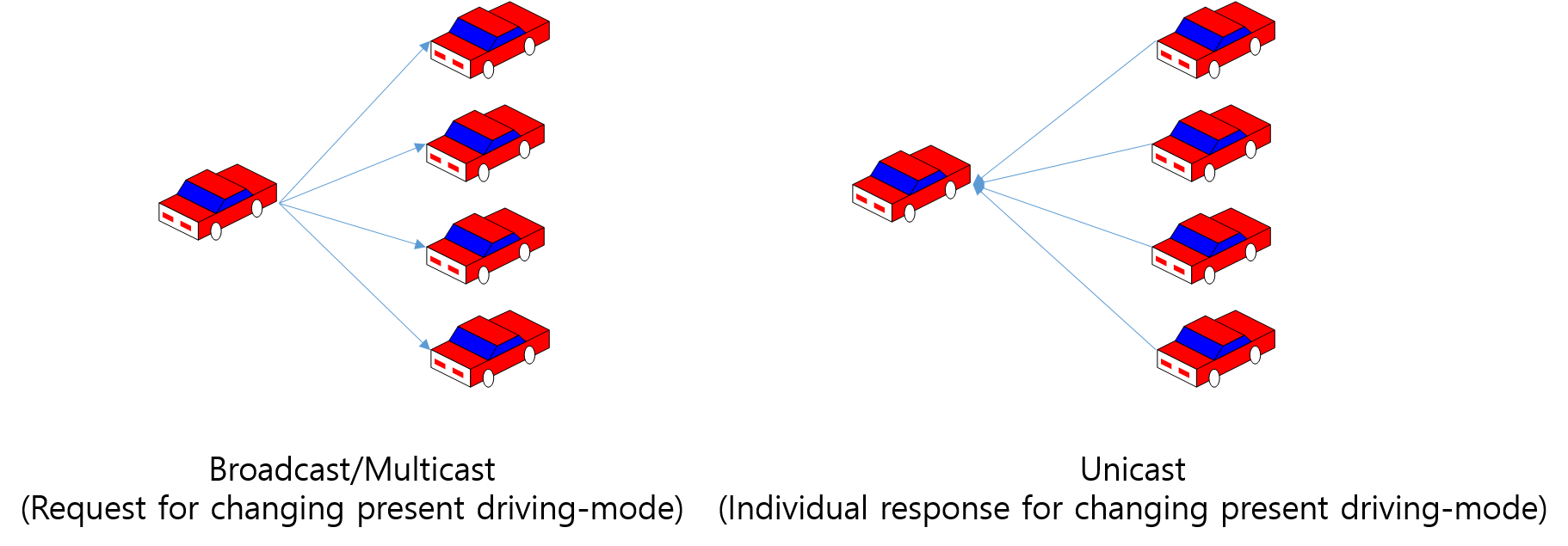


Figure 5.17.1.1-1: Example: required V2V communications for changing driving-mode

Figure 5.17.1.1-1 depicts a required V2V communications as an example.

#### 5.17.1.2 Pre-conditions

1. Vehicles A, B, and C support driving-modes such as autonomous driving, convoy, and platooning.

2. Vehicles D and E do not support eV2X services.

3. Vehicles A, B, and C supports eV2X services.

4. Vehicles A, B, and C are in a platooning group, where the vehicle A is the platoon leader.

5. A platoon leader (vehicle A) in the 2nd lane confronts an obstacle unexpectedly.

6. Behind the platooning group, a non-eV2X enabled vehicle D is followed.

7. A vehicle E is in the 1st lane, where the vehicle E and the platooning group is in the proximity.

8. The platooning group wants to avoid the unexpected obstacle in a safe way.



Figure 5.17.1.2-1: A scenario describing limitation of vehicle platooning

#### 5.17.1.3 Service flows

1. A platooning leader (vehicle A) detects an obstacle, and perceives the vehicle E which is in the proximity to the platooning group.

2. The platooning leader determines which driving-mode is appropriate to be safe. (Here, we assume that individual autonomous driving corresponds to the appropriate candidate for changing driving-mode.)

3. Vehicles B and C are instructed to change the present driving-mode (platooning) from the vehicle A.

4. Vehicles B and C come to be in an autonomous driving-mode after sending a kind of response message regarding changing driving-mode.

#### 5.17.1.4 Post-conditions

1. The platooning with vehicles A, B, and C is changed into a separate autonomous driving.

2. The expected vehicle collision between the platooning group and vehicle E can be avoided.

### 5.17.2 Potential requirements

[PR.5.17-001] The 3GPP system shall be able to support reliable V2V communications between a specific UE supporting V2X applications and up to 19 other UEs supporting V2X applications.

## 5.18 Tethering via Vehicle

### 5.18.1 Description

#### 5.18.1.1 General

This use case enables a vehicle to provide network access to occupants, pedestrians etc. Vehicles have several parameters which are not constrained in the way that a handset is e.g. physical distribution of antennae, available power, heat dispersal, device size, number of antennae, etc. Using some or all of these possible facilities, a high category device may be observed on a vehicle. This high category device may be used to proxy network connectivity to occupants of the vehicle, or pedestrians surrounding the vehicle.

The benefits provided to the handset users are centred on significantly reduced battery consumption but may also include higher throughput. Battery consumption reduction is achieved by lower transmission power at the handset & lower receive sensitivity and increased throughput may be achieved by reduction of network overhead through bundling of multiple individual users under a single context.

The benefits to an MNO are centred on increased network densification correlated with active users, and decreased network overhead due to bundling of individual users under a single context.

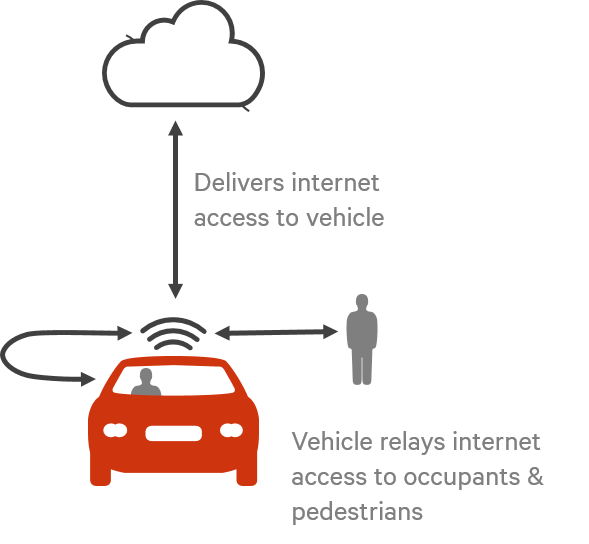


Figure 5.18.1.1-1: Tethering via vehicle

#### 5.18.1.2 Pre-conditions

Vehicle A is V2X capable and is equipped with E-UTRAN access capability.

Occupant A has a mobile device that is V2X capable.

#### 5.18.1.3 Service flows

1. When Occupant A is riding in Vehicle A, their handset obtains access to the network via Vehicle A.

2. Vehicle A relays the communication between Occupant A and the Network using its own network access

3. When Occupant A parks Vehicle A to go for a quick shop nearby the communication between Occupant A and the Network continues via Vehicle A, as long as passenger A is in range of V2P communication.

#### 5.18.1.4 Post-conditions

Occupant B’s handset saved battery power and potentially obtained higher throughput due to gaining network access via Vehicle A’s network connectivity.

### 5.18.2 Potential requirements

[PR.5.18-001] The 3GPP system shall enable a UE supporting a V2X application to obtain network access via another UE supporting V2X application.

NOTE: This requirement does not apply to the case when both UEs are vehicle UEs.

[PR.5.18-002] The 3GPP system shall enable a UE supporting a V2X application to discover another UE supporting V2X application that can offer access to the network.

[PR.5.18-003] The 3GPP system shall enable a UE supporting a V2X application to switch the network access from direct 3GPP connection to an indirect 3GPP connection via another UE supporting V2X application that is connected via 3GPP access to the 3GPP core network, and vice versa.

[PR.5.18-004] The 3GPP system should provide integrity and confidentiality protection (end to end) for the network access traffic of a V2X UE via another such UE.

## 5.19 Use case out of 5G coverage

### 5.19.1 Description

A UE supporting V2X application is equipped with a multi-RAT modem (5G, LTE). The UE is camped on a 5G cell. The UE joins a platoon. The platoon-related messages are transmitted between the UEs in the platoon using 5G technology, as the latency requirement for the application is very low.

The platoon is reaching the cell border, and thus the network triggers a handover to transfer the UEs to the target cell. The target cell is an LTE only cell. LTE is not optimized to support the latency requirements of that application.

Thus, V2V messages needed to support platooning application are exchanged between the UEs in the target cell using device to device communication in 5G New RAT (NR), even though there is no 5G coverage in the target cell. Other traffic is sent via LTE, including other V2X traffic.



Figure 5.19.1-1: Use case out of 5G coverage

### 5.19.2 Potential requirements

[PR.5.19-001] The 3GPP system shall allow UEs supporting V2X application to use 5G RAT for direct communication when the UEs are not being serviced by a 5G cell.

## 5.20 Emergency trajectory alignment

### 5.20.1 Description

#### 5.20.1.1 General

Emergency Trajectory Alignment (EtrA) messages complement cooperative automated driving [31]. Manoeuvre cooperation through EtrA has been invented to assist the driver in hazardous and challenging driving situations to further increase traffic safety [31].

EtrA messages cover sensor data and status information with specific information for cooperative evasive manoeuvre coordination to bring more security in case of unexpected road conditions:

- When a vehicle obtains from on-board sensors the information about obstacles on the road (e.g. pedestrians on the road, loss of goods, deer crossing), it calculates the manoeuvre to avoid an accident.

- This vehicle then informs other vehicles (via 3GPP V2X communication service) about the safety-critical situation immediately. An important reliability of message transfer is expected to support the safety aspect of this information.

- Vehicles in proximity start to align trajectories to perform the emergency reaction cooperatively.

The following Key Performance Indicators (KPIs) are expected:

- Less than 3 ms guaranteed end-to-end latency for cooperative manoeuvre planning within the application time limit [30] [20].

- Throughput of 30 Mbps to exchange messages with 90 kb between vehicles with sensor and trajectory data (0.3 m resolution [30], 100 way-points per trajectory, 50 trajectories per message plus sensor data).

- 99.999 % reliability [31] to avoid trajectory miscalculation on the application layer in safety-critical situation within 500 m communication range [20].

#### 5.20.1.1 Pre-conditions

- Vehicle A, B, C and D supports 3GPP V2X communication.

- Vehicle A, B, C and D supports EtrA on the application.

- Vehicle A detects an obstacle on the road with on-board sensors.

- Vehicle A calculates the driving manoeuvre to avoid crashing without posing a risk to other road users.

#### 5.20.1.2 Service flows

- Vehicle A informs B, C and D about the need of immediate trajectory re-calculation via 3GPP V2X communication service.

- After detecting and informing involved vehicles about trajectory re-calculation, vehicles A, B, C, D calculate possible trajectories and transmit them to all involved vehicles via 3GPP V2X communication service.

- Vehicle A, B, C, D decodes, verifies and evaluates trajectories via known algorithm on application layer and sends message with selected trajectories via 3GPP V2X communication service.

- Vehicle A, B, C and D sends messages via 3GPP V2X communication service to confirm on commonly selected trajectories for each vehicle.

- Vehicle A, B, C, D sends messages with re-calculated and selected trajectories regularly via 3GPP V2X communication service.

#### 5.20.1.3 Post-conditions

- Temporary evasive manoeuvre group performs driving manoeuvre.

- Temporary evasive manoeuvre group finishes sending EtrA messages via 3GPP V2X communication service after the manoeuvre is performed completely and terminated.

### 5.20.2 Potential requirements

[PR.5.20-001] The 3GPP network shall enable communication between UEs with data rate [30] Mbps, less than [3] ms end-to-end latency and [99.999] % reliability within communication range of [500] m.

NOTE: The purpose of the requirement is to be able to provide very fast feedback.

## 5.21 Teleoperated support (TeSo)

### 5.21.1 Description

#### 5.21.1.1 General

While traffic safety as well as accident-free driving is the task of each connected autonomous vehicle, Teleoperated Support (TeSo) enables a single human operator to remotely control autonomous vehicles for a short period of time. TeSo enables efficient road construction (control of multiple autonomous vehicles from a single human operator), snow plowing e.g.

Remote control of vehicle (TeSo) has the following requirements on 3GPP network for V2X communication:

- End-to-End latency less than 20ms for fast vehicle control and feedback [34], [20]

- 25 Mbps Uplink for video and sensors data sent from the vehicle and 1 Mbps downlink data rate for vehicle reception of application related control and command messages via 3GPP V2X communication service

- Reliability of 99.999 %, necessary to avoid application malfunctions [34], [20]

#### 5.21.1.2 Pre-conditions

- Vehicle A is able to drive autonomously and coordinate driving manoeuvres via 3GPP V2X communication service.

- Vehicle A supports TeSo on the application layer (out of 3GPP), it can be in a far end server or in a server hosted by another UE close or not close to the first UE, see Figure 5.21.1.2-1.

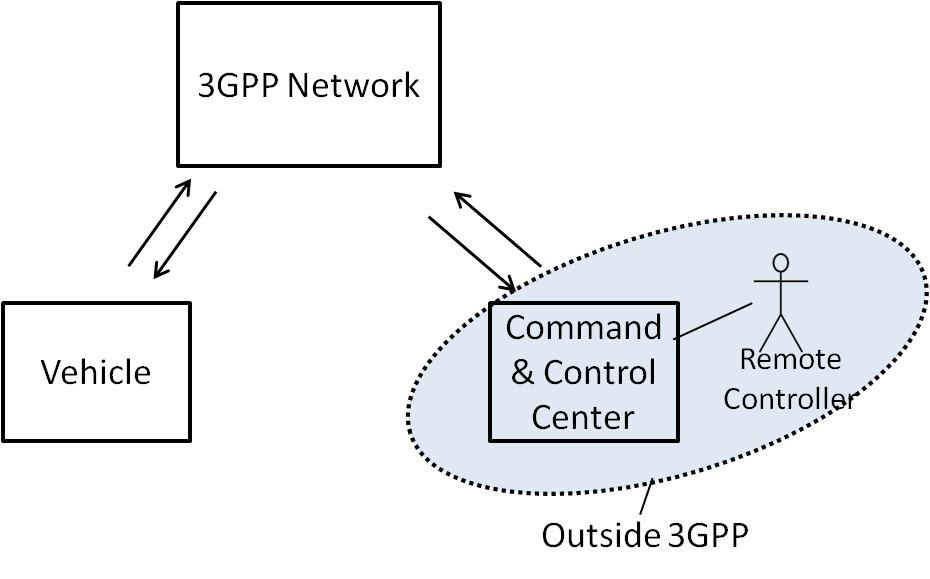


Figure 5.21.1.2-1: TeSo concept description

#### 5.21.1.3 Service flows

- Vehicle A sends TeSo application messages (camera data, sensor data, status data, confirmation etc.) via 3GPP network to the remote operator.

- Remote operator sends TeSo application command messages via 3GPP network to vehicle A.

#### 5.21.1.4 Post-conditions

- TeSo terminates 3GPP V2X communication service, if no further support from remote operator is needed

### 5.21.2 Potential requirements

[PR.5.21-001] The 3GPP network shall enable communication between a UE and a server (e.g. far end server or a server hosted by another UE), to exchange messages to support [25] Mbps in uplink and [1] Mbps in the downlink direction with less than [20] ms end-to-end latency and [99.999] % reliability.

## 5.22 Intersection safety information provisioning for urban driving

### 5.22.1 Description

#### 5.22.1.1 General

The traffic accident occurs at the intersection where the vehicle and pedestrians are crowded. This provides safety information to the vehicles to prevent traffic accident and assist cooperative automated driving function when the vehicles pass through the intersection. Safety information at the intersection involves precise digital map, traffic signal information, pedestrian and vehicles moving status information and location information, generally expressed in LDM (Local Dynamic Map). LDM information will be downloaded into the vehicles periodically or by demand. This information will be needed to know the intersection situation and control automated vehicles (1~3)

This service conducted by Intersection Safety Information System, which consists of road radar, traffic signal and LDM server and RSU. LDM server monitors road situation from road radar and traffic signal, and generates LDM information and delivered to UE through RSU (4).

The 3GPP system capability to support intersection safety information provisioning can be estimated by analyzing LDM message size, the number of activated vehicles and the automated vehicle speed for the intersection traffic model

1. Intersection Traffic Model

The intersection has 4 directions and 2 lanes for each direction. And communication coverage is 250m and 50 vehicles join communication for each direction. The maximum number of vehicles will 200 and the automated vehicles may drive at average speed 60 km/h

2. LDM Message Size and Transmission Rate

LDM message consists of static map information, traffic signal phase information, moving objects information (pedestrian or vehicle). The LDM message size is estimated by 400~500 bytes.

NOTE: The static map with the size 500m x 500m may have 300bytes approximately. The moving objects with ID and a certain speed will have less than 100byets. The total LDM message will have 400~500 bytes*.*

And the automated vehicles moves at 60km/h and they moves 16m per a second. The transmission rate of LDM messages shall be at least 10 for safety applications and it means that LDM messages will be received by 1.6m interval. And the transmission rate of LDM messages shall be more than 50 for automated vehicle control applications and it means vehicle control step will be done by 32 cm distance.

3. Packet Data Rate and Reliability

Based on the given condition that there are 200 vehicles, LDM massage size is 450 bytes and message transmission rate is 100, the required data rate will be calculated by 450 bytes x 8 bits x 200 vehicles x 50 messages per second. It will be 36Mbps approximately. It needs to consider packet transmission efficiency by 60~70%. Therefore, the packet data rate will be 50Mbps. Also LDM messages are used for safety and control applications.

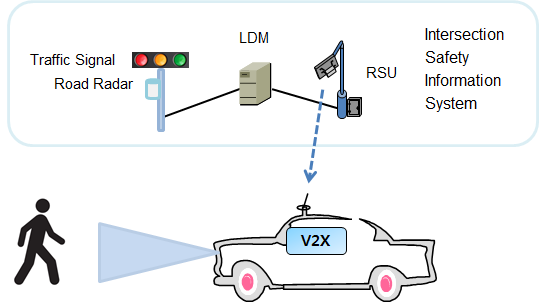


Figure 5.22.1.1-1: Concept of intersection safety information system

#### 5.22.1.2 Pre-conditions

1. The road radar or cameras are installed at the intersection and they will detect the movement of the vehicle and the pedestrians

2. The LDM server will receive the location and movement information on the vehicle and pedestrian and traffic signal information, generate LDM information

3. LDM server and RSU are connected, RSU will transmit LDM information by demand or broadcasting

4. UE or Intersection Safety Information System may initiate radio link setup

5. UE may request LDM information

6. Intersection Safety Information System will download LDM information to vehicle

#### 5.22.1.3 Service flows

1. UE on the vehicle may initiate radio link setup to Intersection Safety Information System

2. UE on the vehicle may request LDM information to Intersection Safety Information System

3. Intersection Safety Information System will download LDM information to UE

4. UE on the vehicle will terminate radio link setup to Intersection Safety Information System

#### 5.22.1.4 Post-conditions

1. UE will receive LDM information and generate warning message to vehicle driver

2. UE will generate vehicle control information for automated vehicle

3. The automated vehicle will avoid collision by vehicles or pedestrians

#### 5.22.1.5 Potential impacts or interactions with existing services/features

Intersection Safety Information System will be able to provide more accurate LDM (Local Dynamic Map) to the automated vehicle when it passes through the intersection safely. It will provide differentiated services

- Pedestrian alert warning

- Vehicle alert warning

- Automated vehicle control by detecting pedestrian and vehicle and traffic signal

### 5.22.2 Potential requirements

[PR.5.22-001] The 3GPP system shall be able to support an average [0.5] Mbps in downlink and [50] Mbps in uplink.

[PR.5.22-002] An RSU shall be able to communicate with up to 200 UEs supporting a V2X application.

[PR.5.22-003] RSU shall be able to support [50] packet transmission per a second with an average message size [450] bytes.

## 5.23 Cooperative lane change (CLC) of automated vehicles

### 5.23.1 Description

#### 5.23.1.1 General

On a multi-lane road, a lane change manoeuvre could be initiated by a vehicle. To ensure safe and efficient lane change, exchange of trajectory plans between vehicles is necessary. Cooperative Lane Change V2X scenario involves vehicles exchanging their intended trajectories to coordinate their lateral (steering) and longitudinal controls (acceleration/deceleration) to ensure a smooth manoeuvre.

Two sets of Key Performance Indicators (KPIs) are supported:

Set 1: the vehicle is semi-automated driving

- Small Message size 300-400 Bytes.

- Less than 25ms end-to-end latency is needed for CLC packets exchange among the involved vehicles.

- Reliability of 90% is needed to ensure that the participating vehicles receive the update trajectory plan for the lane change manoeuvre.

Set 2: the vehicle is fully automated:

- The Message (UE location, sensor data) size up to 12 KBytes.

- Less than 10ms end-to-end latency is needed to exchange trajectory plan among the involved vehicles.

- Reliability of 99.99 % is needed to ensure that the participating vehicles receive the update trajectory plan for the lane change manoeuvre.

#### 5.23.1.2 Pre-conditions

- Vehicles A, B, C support message exchange via 3GPP communication.

- Vehicles B and C are located at the adjacent lane than A.

- Vehicle A wants to change lane and insert between vehicle B and C into the adjacent lane.

- Vehicles A, B, C based on periodic messages that are broadcasted are aware about the neighbouring vehicles and their location.

#### 5.23.1.3 Service flows

- Vehicle A detects the need for a lane change and requests the gap creation.

- Vehicle B and C confirm that they will participate in this manoeuver and create the gap based on the agreed plan.

- Vehicle A is informed about the creation of the required space between vehicles B and C.

- Vehicle A moves into the selected lane by continually transmitting periodically its trajectory plan to other involved vehicles via the 3GPP communication service. The trajectory plan is updated based on the evolution of the manoeuvre and the locations of Vehicles B and C.

#### 5.23.1.4 Post-conditions

- Vehicles A, performs the lane change with the cooperation of Vehicles B and C.

### 5.23.2 Potential requirements

KPIs for set 1:

[PR.5.23-001] The 3GPP network shall support message exchange between UEs of message with less than [25] ms latency, [90] % reliability and message size [300-400] Bytes with semi-automated driving.

KPIs for set 2:

[PR.5.23-003] The 3GPP network shall support message exchange between UEs with less than [10] ms latency, with [99.99] % reliability and maximum message size of [12] KBytes with full automated driving.

## 5.24 Proposal for secure software update for electronic control unit

### 5.24.1 Description

#### 5.24.1.1 General

A car Electronic Control Unit (ECU) is a generic term for a software module that controls the electronics within a car system; this could be anything from the steering wheel to the brakes and with automated car driving and this becomes a key part of the car that will possibly need regular software updates. These updates are subject to major security checks and as expected this is an important topic within the automotive industry.

#### 5.24.1.1 Pre-conditions

None.

#### 5.24.1.2 Service flows

The diagram below considers the case when an UE is using eV2X to support automated driving and there is an update required to the ECU. The procedural flow is described as follows:

- UE is synchronised e.g. via Bluetooth to an ECU.

- Suppose a scenario where a car stops in a filling station and connects following a registration procedure to a nearby RSU.

- When connected, the RSU detects the software module version of the ECU in the car via communication with the UE and detects that an update is needed. This is based on the list available to the RSU from a broadcast message from a car manufacturer cloud server.

- The RSU will notify the UE that an update is required to the ECU and with the list of updates required. The User will be able to choose the update required from the list of updates for example. Also the user should be able to reject/defer the update required to ECU.

- If the user chooses an update to the ECU, then additional security procedures should take place so the software download is definitely not from a wrong source and it’s actually the correct version.

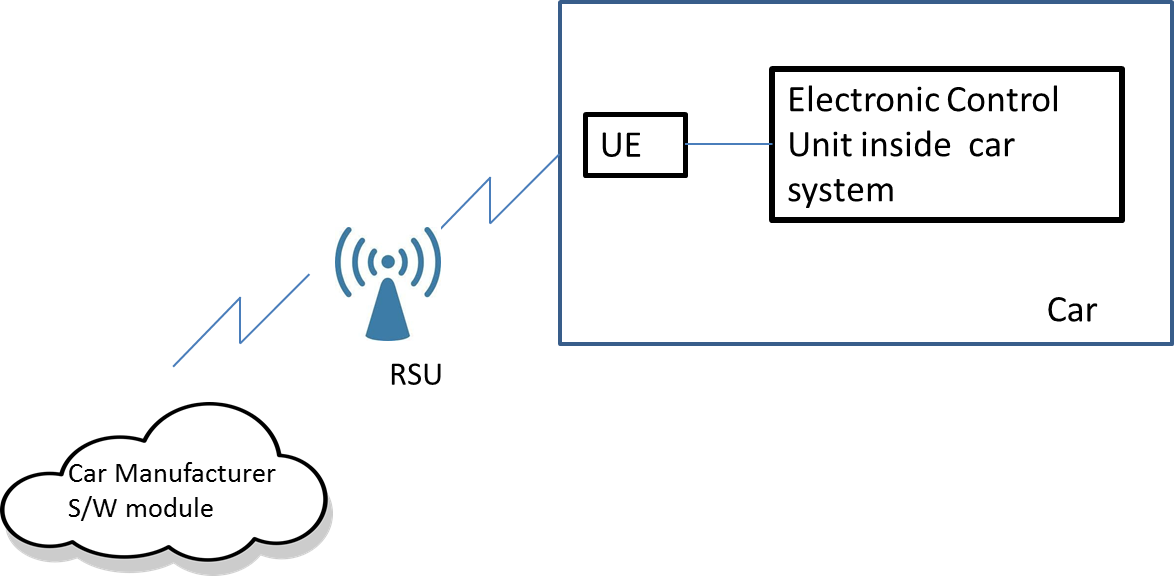


Figure 5.24.1.2-1: secure software update for electronic control unit

#### 5.24.1.3 Post-conditions

None.

### 5.24.2 Potential requirements:

[PR.5.24 -001] The 3GPP System shall provide a secure mechanism to update V2X applications (e.g. an Electronic Control Unit (ECU)).

## 5.25 3D video composition for V2X scenario

### 5.25.1 Description

This use case consists of multiple UEs supporting V2X application moving in an area. The UEs may belong to the same PLMN or different PLMNs. The UEs may also be camped in different cells.

Those UEs have a camera and they take a video of the environment, and send this video to a server. The server can be in the cloud or in the near the UE point of attachment to enable edge computing. The server will then post-process the videos received and combine the information in order to create a single 3D video of the environment. The 3D video can then be used for analysis in different scenarios, such as sharing the video with end-users in a car race, evaluation of possible accident by law enforcement, etc.

The UEs location information, allows the server to accurately represent the location, relative speed and distance of vehicles, pedestrians, and any objects in that area.

### 5.25.2 Potential requirements

[PR.5.25-001] The 3GPP system shall provide a mechanism so that a server outside the 3GPP domain is able to time-synchronize different videos received from different UEs, each UE having a maximum absolute speed of 250 Km/h.

[PR.5.25-002] The 3GPP system shall support a data rate of [10] Mbps in the uplink per UE (to support 4K/UHD video).

[PR.5.25-003] The 3GPP system shall support a mechanism for UEs to be able to calculate [50] absolute location fixes per second, with [TBD] meters of accuracy for each location fix.

NOTE: This requirement is to support 250 Km/h (69 meters per second), so 50 location fixes per second implies one location fix every 1.4 meters.

## 5.26 QoS aspect of vehicles platooning

### 5.26.1 General description

Platooning is a coordinated mobility of group of vehicles, sharing manoeuvre and other information with each other. As described in previous sections, it increases traffic efficiency and reduces fuel consumptions.

One of most critical requirements for platooning is that the information flow between platoon members should be performed in a timely and reliable way. Because the time gap or distance gap between vehicles within a platoon is small, late arrival of the status information of the preceding vehicle or loss of manoeuver information can result in uncomfortable situations. These gaps between the vehicles should be set to avoid potential collision risk.

Thus, the platooning applications installed in a vehicle will adjust the time/distance gap based on the achievable QoS of connectivity. When low latency and high reliability can be achievable, the gap can be shorter. On the other hand, when latency is high or packet loss rate is high, the gap between vehicles need to be longer. If the QoS cannot fulfil the platoon application’s requirement at all, the platoon itself should not be composed from the start.

### 5.26.2 Adjustment of gaps for platooning

#### 5.26.2.1 Description

Following is a service flow in which the gaps within a platoon are adjusted:

1. A logistics company called PTruckers owns lots of trucks and connects CityA and CityB with parcel delivery service. Due to several reasons, road transportation is the only way to connect CityA and CityB. To optimize the service, PTruckers starts to apply platooning application to its vehicles. While the depots of PTruckers are located within city center where there is good network coverage, there are areas with weak signal or areas outside of coverage along the road between CityA and CityB.

2. Three vehicles of PTruckers are scheduled to leave from the depot in CityA to the depot in CityB. One human driver rides on VTruck1, which is the leading vehicle. VTruck1 is followed by VTruck2 and VTruck3. VTruck1, VTruck2 and Vtruck3 belongs to the same platoon.

3. Platooning application checks the communication QoS (e.g. latency and reliability) among the vehicles. Because the currently available QoS are good enough and the available QoS for the next 10 km is expected to be similar, the application sets 0.1 second time gap between the vehicles. The vehicles starts to move

4. As the platoon approaches the edge of the CityA, the platooning application is notified with updated forecast of QoS. According to the notification, starting from 10 seconds later, the available QoS for the next 100 km along the route is lower than the current level. Because expected guaranteed latency is longer than the currently supported guaranteed latency, the platooning application decides to gradually increase the time gap between the vehicles from current 0.1 second to 0.5 second.

5. As the platoon moves further away from the CityA, it will soon move out of any network coverage. With use of direct communication between the vehicles, the platooning application continues to work even when there is no network coverage. However, due to lack of centralized network control, the expected guaranteed latency and the reliability of communication is a little bit worse than when the platoon was in network coverage. This updated forecast information is delivered to the platooning application. Now, the application starts to increase further the inter-vehicle distance and relies more on information obtained through sensors.

#### 5.26.2.2 Potential requirements

The following potential requirements are derived from this use case.

[PR.5.26.2-001] The 3GPP system shall be able to provide V2X applications with supported QoS information, regardless of whether a UE related to the V2X application is in coverage of a 3GPP radio access network or not.

NOTE: This requirement may not be applicable all scenarios. For example, when QoS information is generated in the 3GPP network and UE is out of coverage, V2X application cannot be provided with the QoS information.

[PR.5.26.2-002] The 3GPP system shall be able to provide V2X applications with updated QoS, from the multiple QoS previously provided by the application, when the QoS changes.

[PR.5.26.2-003] The 3GPP system shall be able to additionally provide V2X application with prediction on how long the QoS will be maintained, when the 3GPP system provides the V2X applications with supported QoS information.

[PR.5.26.2-004] The 3GPP system shall be able to additionally provide V2X applications with prediction on geographical area where the QoS will be maintained, when the 3GPP system provides the V2X application with supported QoS information.

## 5.27 QoS aspects of advanced driving

### 5.27.1 General

According to [38], there are several levels for automated driving. Based on design decision by manufactures or by regulation, an appropriate level of automated driving will be designated per each driving environment.

Based on the implementation or approach taken by each manufacturer or the environment where each vehicle is located, whether to engage automated driving or not needs to be controlled by the V2X service either in the vehicle or in the cloud of remote back-end. Following are examples:

- A vehicle can operate as an automated vehicle when its future driving route is within areas for which the driving tests have already been finished to confirm that the vehicle can drive safely.

- Due to capability limitations such as real-time data/image processing capability, some portion of computation for sensor data processing and/or driving manoeuvre decision should be performed in the cloud. In this case, the V2X service may allow the vehicle to be automated only when it can reliably connect to the vehicle.

- To resolve potential liability issue, the V2X service may want to continuously monitor the status of the vehicle and the surrounding environment.

- Depending on regulations and conditions, the permission to use of automated driving can differ per each environment. For example, regulations may specify that automated driving is allowed only on the highway. Or, due to heavy rain, local road authority may decide not to allow the use of automated driving in a certain road. Because of the amount of information, the vehicle may not locally store all information required for the decision of whether to use automated driving mode or not for each different environment.

In addition, the comfort, quality of experience of the passenger or existence of potential human driver should be considered. If use of automated driving is granted only when the vehicle is connected to the V2X service in the cloud, sudden loss of connection may kick off pre-programmed emergency routine in the vehicle. In the worst case, the vehicle suddenly make a full stop or pull over, if enough time is not given for human to take over the control of a vehicle. This impacts negatively human experience of automated driving.

### 5.27.2 Assistance to automated driving

#### 5.27.2.1 Service flows

Following is overall service flow where a human in a vehicle requests the vehicle to drive automatedly.

1. VehicleA is a vehicle capable of supporting automated driving. VehicleA is manufactured by MFG\_A and controlled by a V2X service using a V2X application. The V2X application can reside either in VehicleA and / or in the cloud of MFG\_A. The V2X service of VehicleA is supported through MNO\_A, which is an operator with which MFG\_A has established a service contract. Knight is the owner of the VehicleA.

2. Knight leaves his home in CityA and rides a vehicle called VehicleA. Knight requests VehicleA to go CityB and VehicleA forwards the request to the V2X application.

3. The V2X application calculates and decides a route toward the destination. The V2X application queries MNO\_A whether connections can be provided along the route. For a certain service, the V2X application also queries MNO\_A whether a specific QoS can be supported along the route.

4. Based on internal information for its core network and radio network coverage, MNO\_A check whether the route is within its network coverage. MNO\_A replies back to the V2X application regarding the area where connection can be provided, the area where connection cannot be provided, and supported QoS in case connection is provided.

5. The V2X application finalizes the decision regarding the route and the use of automated driving per road environment along the route. Based on the information in step 4, the V2X application may provide the VehicleA with the information regarding the use of automated driving per segment of the route.

6. Based on information from the V2X application, VehicleA starts automated driving.

#### 5.27.2.2 Potential Requirements

[PR.5.27.2-001] The 3GPP system shall be able to provide a standardized interface to enable exposure of the following services and capabilities to V2X applications, to support the V2X application to adjust its service offering:

- [PR.5.27.2-001a] The 3GPP system shall be able to support V2X applications to request information on whether connectivity can be provided in a certain geographical area.

- [PR.5.27.2-001b] The 3GPP system shall be able to provide V2X applications with information on whether connectivity can be provided in a certain geographical area.

- [PR.5.27.2-001c] The 3GPP system shall be able to support V2X applications to request information on whether specific QoS can be provided in a certain geographical area.

- [PR.5.27.2-001d] The 3GPP system shall be able to provide V2X application with information on whether the requested QoS can be provided in a certain geographical area.

### 5.27.3 Authorization to support automated driving

#### 5.27.3.1 Service flows

Following service flow can be applicable.

1. Manufacture MFG\_A provides MNO\_A with an information regarding a V2X application such as an IP address to e.g. identify the access from an V2X application.

2. MNO\_A configures its network with what kind of information of the network can be provided to this V2X application. For example, the V2X application can inquire the network whether coverage can be provided in certain area, but it cannot inquire the network of information regarding the location of each radio network node.

3. When the V2X application requests network coverage information, MNO\_A’s network checks the authenticity of the V2X application and the request. Once the authentication of the V2X application is successful, the MNO\_A’s network further checks whether the information requested is authorized to V2X application.

4. If the requested information is authorized for the V2X application, MNO\_A responds to the V2X application with the requested information. Based on the service agreement, granularity of information or contents of response can vary.

#### 5.27.3.2 Potential Requirements

[PR.5.27.3-001] The 3GPP system shall be able to authenticate V2X application for accessing exposed services and capabilities of the 3GPP system.

[PR.5.27.3-002] The 3GPP system shall be able to authorize V2X application to access exposed services and capabilities of 3GPP system.

[PR.5.27.3-003] The 3GPP system shall be able to provide authorized information to V2X application.

### 5.27.4 Notification of updated information to support automated driving

#### 5.27.4.1 Service flows

Following service flow can be applicable.

1. When the V2X application requests information from MNO\_A, it further indicates whether it wants to be notified if there are any changes in the previous provided information.

2. When MNO\_A sends response to the V2X application with the requested information, it keeps records of the delivered information.

3. MNO\_A monitors whether there is any potential QoS change in the area where connectivity needs to be provided. Or, if the previous negotiated QoS cannot be guaranteed for a certain area due to radio resource congestion or failure of some NFs, this event can be also monitored.

4. If there is a change compared to the previous response to the V2X application, MNO\_A delivers new information to the V2X application.

5. Based on new information, the V2X application checks whether there is a need to update information sent to VehicleA.

In this service flow, to minimize impact to user experience, the potential change of QoS should be detected and notified in several second earlier, which can be determined from service requirements.

#### 5.27.4.2 Potential Requirements

[PR.5.27.4-001] The 3GPP system shall be able to provide a standardized interface to enable the exposure of the following services and capabilities to V2X applications, to support V2X application to adjust its service offering:

- [PR.5.27.4-001a] The 3GPP system shall be able to support V2X applications to subscribe to information on the availability or unavailability of connectivity for a certain geographic area.

- [PR.5.27.4-001b] The 3GPP system shall be able to provide V2X applications with updated information on the availability or unavailability of connectivity within a certain geographic area, at least a certain amount of time before when the actual change occurs.

- [PR.5.27.4-001c] The 3GPP system shall be able to support V2X applications to subscribe to information on the QoS which can be provided within a certain geographic area.

- [PR.5.27.4-001d] The 3GPP system shall be able to provide V2X applications with updated information on the QoS that can be provided within a certain geographic area, at least a certain amount of time before when the actual change occurs.

### 5.27.5 Support for adjustment and big data transport

#### 5.27.5.1 Service flows

For MNO to have capability to support V2X services to adjust their functions based on the change of QoS, the information gathering and analysis of the gathered information is needed. Following service flow can be applicable.

1. VehicleA is able to calculate its current location. VehicleA is also able to keep records of the connectivity-related parameters and performances. For example, VehicleA logs when data packet transmission/reception occurs and identification information for the data packets, along with location information.

2. Radio access network and/or core network is also able to keep records of the connectivity-related parameters, performances and events.

3. VehicleA starts journey and it is configured by MNO\_A to log transmission/reception events and related time and location information. In addition, the network is also configured to log similarly.

4. During the journey, due to some reason, VehicleA disengages automated driving.

5. VehicleA arrives at the destination. VehicleA reports to V2X application with information related to disengagement of automated driving.

6. Manufacturer MFG\_A receives similar event reports from other vehicles of specific vehicle segments. To fully analyse the event, MFG\_A requests MNO\_A’s assistance.

7. MNO\_A calculates the time and location relevant for the MFG\_A’s request. Based on the calculation, MNO\_A requests VehicleA to upload relevant log information. Due to information sharing restriction, the log information is not directly shared to MFG\_A. After internal processing, and based on service agreement and regulation, processed information is shared to MFG\_A by MNO\_A.

#### 5.27.5.2 Potential Requirements

[PR.5.27.5-001] The 3GPP system shall be able to support efficient and secure mechanism to gather information (e.g. location information, reliability information, timing information, latency information, velocity information and so on.), which enables 3GPP system to support V2X application to adjust its service offering.

NOTE: It is FFS whether Minimization of Driving Test can support this requirement in consideration of the various velocity of vehicular environment.

[PR.5.27.5-002] Based on service agreement and operator policy, the 3GPP system shall be able to provide authorized V2X application with information enabling V2X application to adjust its service offering, based on gathered information.

[PR.5.27.5-003] The 3GPP system shall be able to minimize impact to system performance, while supporting a mechanism to gather information, which enables 3GPP system to support V2X application to adjust its service offering.

### 5.27.6 Support of automated driving in multi-PLMN environments

#### 5.27.6.1 Service flows

Because of ‘mobility’, vehicles are expected to cross international borders or PLMN borders. Depending on the extent to which service agreement is made, two scenarios can be assumed:

- Scenario 1: A vehicle manufacturer makes multiple service agreements with MNOs. For example, the manufacturer has service agreement with MNO A for France and with MNO B for Germany. In this case, when the vehicle crosses border from Germany to France, the MNO for the vehicle changes from MNO B to MNO A.

- Scenario 2: A vehicle manufacturer has a single service agreement with a MNO. For example, the manufacturer has service agreement with MNO B. In this case, when the vehicle crosses border from Germany to France, the used MNO for the vehicle in France can be controlled depending on MNOs with which the MNO B has roaming agreements.

While above scenarios are described in terms of international border, similar description can be applied to PLMN borders of the same country.

Regardless of actual scenarios in place, from passenger experience point of view, automated driving should not be interrupted even when the vehicles cross borders as long as automated driving is permitted by regulation.

Following service flow can be applicable.

1. Information on current location and destination is delivered to the V2X application. The route is calculated by the V2X application and the V2X application queries MNO\_A whether QoS can be supported along the route.

2. MNO\_A checks whether connectivity service can be provided over the requested route. MNO\_A estimates that part of the route is outside of MNO\_A’s coverage area.

3. VehicleA starts journey with connection to MNO\_A.

4. VehicleA approaches the boundary of MNO\_A. MNO\_A selects target MNO from candidate MNOs which can support required QoS of the V2X application. The selected MNO is MNO\_B.

5. As VehicleA crosses the border of MNO\_A, the connection is covered through involvement of MNO\_B. While the radio network is changed from MNO\_A to MNO\_B, the passenger does not notice this change because there is no changes in the engaged automated driving. It is expected that interruption during the MNO change does not impact the V2X application.

#### 5.27.6.2 Potential Requirements

[PR.5.27.6-001] The 3GPP system shall be able to support service continuity for a UE even when the PLMN serving the UE changes.

### 5.27.7 Reliable and guaranteed connectivity service

#### 5.27.7.1 Service flows

Life-cycle of vehicles is longer than that of general consumer electronics devices such as smartphone. Due to long life-cycle, people performs periodic maintenance measures for various components of their vehicles. But, due to regulation and/or certification, some components such as computing unit in the vehicle cannot be replaced and upgraded. In this case, the vehicle with limited processing capacity cannot handle advanced algorithm in real-time or the information gathered by sensors cannot be fully interpreted by the vehicle alone. To assist the vehicle, one option is to use edge-computing so that sensor data from the vehicle is uploaded to edge-computing environment and processing result is sent back to the vehicle.

In the above scenario, reliable connectivity between the vehicle and the edge computing environment is critical. When the connectivity between the vehicle and the edge computing environment cannot be sustained, automated driving should be disengaged. But this transition cannot be done immediately. For example, in worst case where the driver falls asleep during the high level of automated driving, it will take several seconds for the driver to wake up and to grip the driving wheel.

Thus, connectivity service needs to be guaranteed in terms of time, depending on the characteristics of the impacted V2X service. This is in turn related to how much earlier the change in QoS needs to be notified in advance. For example, if a vehicle is designed to switch off automated driving mode for a QoS degradation and if a driver needs at least 10 seconds to prepare manual-driving, the V2X service should be notified at least 10 seconds before the potential change in the supported QoS of connectivity. And from the time when the notification is made and to time when the actual change in the QoS occurs, the pre-negotiated QoS should be maintained.

Following is a service flow for guaranteed service provision.

1. Manufacturer MFG\_A configures the functionality of VehicleA and the V2X application to support automated driving function. While raw data from the sensors installed in the VehicleA is good enough, the processing unit in the VehicleA is not enough to handle state-of-the-are software processing. Thus, when higher level of automated driving is used, the vehicle is configured to deliver sensor data to V2X application, the V2X application processes the sensor data, and the driving command is sent back to VehicleA.

2. The current location information and the destination information is sent from VehicleA to the V2X application. Based on service requirement of the V2X application, V2X application queries MNO\_A whether required QoS can be provided over next 10 seconds for the planned road segment over which the VehicleA will drive.

3. Based on the information provided by the V2X application and internal information, MNO\_A checks and estimates whether the requested QoS can be provided for the calculated route for the next 10 seconds.

4. If it is estimated that the QoS can be supported for the next 10 seconds, the MNO\_A responds to the V2X application that the QoS is guaranteed for the next 10 seconds. After sending response, the radio network and the core network will take necessary measures to provide the negotiated QoS for that 10 seconds. For example, because safety-issue is involved, the resource used for the connectivity between VehicleA and the V2X application is prioritized or can be reserved in the relevant nodes. Network maintenance or rebooting should be avoided for that period.

#### 5.27.7.2 Potential Requirements

[PR.5.27.7-001] The 3GPP system shall be able to provide mechanisms to support the estimation of potential QoS for a certain time period and a certain geographical location, with negotiated accuracy level to support V2X applications to adjust their service offerings.

[PR.5.27.7-002] The 3GPP system shall be able to provide mechanisms to support the provision of potential QoS at a certain time period and a certain geographical location after informing the V2X applications with the QoS information, the time period and the geographical location.

## 5.28 QoS aspect of remote driving

### 5.28.1 Notification of QoS change for remote driving application

#### 5.28.1.1 Description

Remote driving requires specific levels of QoS for safe operation of the application, as described in [TS 22.186]. Remote Driving applications allow a remote driver that is not sitting in the vehicle to undertake the control of the vehicle and drive remotely the vehicle, in an efficient and safe manner, from the current location to the destination.

If then the communication between the remote vehicle and the remote driver could be suddenly interrupted. This could affect the traffic flow, the efficiency of the remote driving application and the safety of the passengers of the remote vehicle and/or surrounding vehicles.

An early notification about a potential QoS degradation from the network to the Remote Driving application, could allow the remote driver or the remote vehicle to adapt themselves to the expected communication conditions (e.g., the vehicle to fall back to a safe state or to adapt its speed) and mitigate the impact of sudden QoS changes:

* If the network estimates that the conditions will be potentially bad in a certain future, there is an interest to notify the application of this potential downgrade in advance to allow it to slow down the car.
* When the network conditions are better, there is interest to notify the application so it requests a new QoS and applies higher car speed.

#### 5.28.1.2 Pre-conditions

The vehicle has some autonomous capabilities.

The remote vehicle and the remote driver can establish an authenticated and secure communication channel via 3GPP V2X communication service, and thus exchange information (e.g., vehicle information, driving commands).

#### 5.28.1.3 Service Flows

1. The driver of the vehicle asks a remote driving service to undertake the control of the vehicle and drive safely.
2. A remote driver undertakes the control of the vehicle.
3. The vehicle transmits video streams to the remote driver, via 3GPP network, which help the remote driver to identify road conditions, neighboring vehicles and objects on the road.
4. Based on the perceived environment the remote driver controls the vehicle, while manoeuvre commands are transmitted from the remote driving application to the vehicle, via 3GPP network.
5. The 3GPP network estimates a future degradation of the network condition that will not allow to keep the current guaranteed QoS for the 3GPP communication service between the remote driving application server and the vehicle. This can be based e.g. on radio technologies in the area the car is driving into or foreseen network conditions.
6. The 3GPP network notifies the remote driving application about the expected degradation of the QoS.
7. Based on the provided notification by the 3GPP network, the vehicle falls back to a safe state or it is decided to adapt the speed by the remote driver drives the vehicle.

#### 5.28.1.4 Post-conditions

The remote driving application has taken the appropriate action to adapt itself and the new QoS, taking into account its view on best safety and efficiency action to be done.

#### 5.28.1.5 Potential Requirements

[PR.5. 28.1-001] The 3GPP network shall be able to notify an application server supporting a V2X application when it estimates that the QoS might need to be downgraded compared to the currently agreed QoS of a 3GPP connection e.g. due to expected bad network conditions, change of radio technology, radio congestion.

[PR.5. 28.1-002] The 3GPP network shall be able to negotiate alternative QoS with the V2X

[PR.5. 28.1-003] The 3GPP network shall notify an application server supporting V2X application that the current QoS might change indicating the specific period of time and/or geographical area it applies.

[PR.5. 28.1-004] The 3GPP network shall be able to notify an application server supporting a V2X application when it estimates that the QoS can be upgraded compared to the currently agreed QoS of a 3GPP connection e.g. due to expected improved network conditions, change of radio technology, less cell occupation..

### 5.28.2 Support of remote Driving

#### 5.28.2.1 General

When remote driving application is running, there is no need for the human in the vehicle to drive. Instead, a human driver or a driving software in remote location makes analysis of the situation around the vehicle, makes driving decision and sends driving decisions back to the vehicle. Accordingly, connections between the vehicle and the remote back-end is always required while the remote driving application is running.

#### 5.28.2.2 Disengagement of autonomous driving

In the following case, transition from autonomous driving to remote driving can occur:

1. Jack owns a vehicle capable of higher level of autonomous driving. There is no need for Jack to drive and he actually does not know how to drive. When Jack leaves home to his office, his vehicle is engaged with highest level of autonomous driving.

2. The route that the vehicle takes is always the same. But, one day, on his way to office, due to bad road situation, one of sensors installed in the vehicle is severely damaged.

3. Due to the sudden loss of the sensor, the higher level of autonomous driving is no longer supported by the vehicle

4. Because Jack cannot drive, the vehicle contacts emergency service center of the vehicle manufacturer. The service center proposes remote driving and Jack accepts the offer.

5. The service center activates remote driving application toward the vehicle. The remote driving application checks whether connectivity can be provided up to the original destination. In addition, based on the capability of the vehicle and the requirements of the application, the remote driving application calculates the required QoS of the connectivity toward the vehicle and checks whether the QoS can be supported or not, on the way to the original destination. In this step, potential interaction with 3GPP system is required to get necessary information.

6. Because the workplace of Jack is located in suburban area, the required QoS cannot be provided all the way to the office. Thus, the remote driving application calculate alternative intermediate destination up to which the QoS requirement of the remote driving application can be supported.

7. The remote driving application drives the vehicle to the intermediate destination, where Jack can take taxi to his office.

#### 5.28.2.3 Provision of freedom of mobility

There are various scenario in which remote driving can provide mobility assistance to people. For example, due to the increase of car accidents caused by the elderly people, these people prefer not to drive or driving licences can be voided for people over certain ages. Remote driving application can play an important role in supporting daily lives of these people.

1. Karl is a senior living in a nursing home. While the seniors living in that nursing home cannot drive, there is a need to support their mobility. Thus, the nursing home owns several vehicles in which a remote driving application is installed. The remote driving application is run by a company called RDrive with which the nursing home has service contract.

2. On Monday, Karl receives an invitation to the birthday party of Michael, which will be held in 7:00 PM Wednesday. Karl calls RDrive to make a reservation of mobility support. RDrive checks with a contracted MNO whether the required QoS to run the remote driving application can be guaranteed along the route at the scheduled time of departure. When the QoS can be met, RDrive requests reservation of the connectivity service to the MNO and the MNO replies with confirmation. RDrive also sends confirmation to Karl that the mobility service can be provided and the vehicle will leave on 6:30 PM Wednesday. With this confirmation, Karl replies to Michael that he will attend the party.

3. At 6:30 PM Wednesday, Karl rides on the vehicle and the remote driving application controlled by RDrive starts. Because connectivity service with a requested QoS is reserved and provided along the route, there is no interruption to remote driving application. Karl safely arrives at Michael’s home at 6:50 PM.

#### 5.28.2.4 Potential requirements

The following potential requirements are derived from this use case.

[PR.5.28.2-001] The 3GPP system shall be able to provide a standardized interface to enable exposure of the following services and capabilities to V2X application, to support the V2X application to adjust its service offering:

- [PR.5.28.2-001a] The 3GPP Core Network shall be able to support a V2X application to request information on whether connectivity service can be provided for a certain geographic area and time.

- [PR.5.28.2-001b] The 3GPP Core Network shall be able to provide a V2X application with information on whether connectivity service can be provided for a certain geographic area and time.

- [PR.5.28.2-001c] The 3GPP Core Network shall be able to support a V2X application to request information on whether specific QoS can be provided for a certain geographic area and time.

- [PR.5.28.2-001d] The 3GPP Core Network shall be able to provide a V2X application with information on whether the requested QoS can be provided for a certain geographic area and time.

- [PR.5.28.2-001e] The 3GPP Core Network shall be able to support a V2X application to request reliable provision of connectivity with specific QoS parameter for a certain geographic area and time.

- [PR.5.28.2-001f] The 3GPP Core Network shall be able to provide a V2X application with response on whether the request on reliable provision of connectivity service with specific QoS parameter for a certain geographic area and a certain time is accepted or not.

- [PR.5.28.2-001g] The 3GPP Core Network shall be able to provide a V2X application with recommendation of QoS parameters that can be provisioned for connectivity services for a certain geographic area and a certain time.

[PR.5.28.2-002] The 3GPP system shall be able to support means to provide connectivity service with specific QoS for a certain geographic area, based on the response sent to V2X application.

### 5.29 QoS Aspect for extended sensor

#### 5.29.1 Description

The extended sensor use cases are composed of sensor data collection to construct local dynamic map and the state map sharing, sensor data shared to extend sensor range, different all round video data shared for automatic drive. The 3GPP system will support different V2X applications on above use cases and following aspects need to be considered:

1. The V2X service provider may appoint key sensor data suppliers (Vehicles and RSUs) to construct collective situational awareness. The key sensors can be owned by the V2X service provider or have contracts with V2X service provider to provide more detail and specific sensor data for V2X service. Thus, the key sensors need more reliable and specific communication supporting. And the V2X service provider may adjust them while the vehicles are moving or the environment is changed.
2. Based on the collected sensor data, the local dynamic map server continues to build the all around local dynamic map, the V2X service provider may provide different local dynamic map or extended sensor service for different user e.g. different data rate, different accuracy, different range, different update cycle etc. Thus, the communication service need to support different data rate, different reliability, different information deliver frequency etc.
3. Considering different computing capabilities, the vehicles and RSUs may share different sensor data type i.e.raw or processed sensor data, the sensor data type can be selected by V2X service provider and different latency\ data throughput\reliability should be adaptive to support different kind of sensor data types.

#### 5.29.1.1 Pre-conditions

Vehicle A, B, C have been installed sensors and V2X capability. The RSU X, Y have been installed camera, V2X capability and locate in the traffic intersections of downtown.

VehicleA, B, C are installed the V2X application “MAPS for V” which belongs to map company MAPS to collect sensor data and receive LDM (Local Dynamic Map). VehicleA has a contract with the map company MAPS to get realtime higher accuracy local dynamic map to support its automatic drive mode.Vehicle B and Vehicle C are normal cars and subscribe free map service from MAPS.

The RSUX, Y belong to Road company ZROAD and have a contract with MAPS to provide traffic information to MAPS through the V2X application “MAPS for I” which belong to MAPS and is installed in the RSUs.

The company MAPS has a contract with communication Operator X:

* Operator X supplies higher level communication and computing service for MAPS which may be in cloud or the local data center.
* Operator X supplies higher level communication service to MAPS user who is chosen by MAPS.

Vehicle A, B and C, RSU X, Y are normal users of Operator X.

#### 5.29.1.2 Service Flow

1. Vehicle A, B, C begin driving in different roads in downtown. The application “MAPS for V” in these vehicles are opened and begin to collect sensor data around the vehicles. The “MAPS for I” in the RSUs are working all the time to collect vehicles sensor data and traffic information then delivers them to LDM server which may locate in a local data center or in the Operator X’s cloud.

2. Considering RSU X location and Vehicle A, B locations and trajectorys, they are chosen as the key sensor data suppliers for downtown LDM construction. This chosen information is notified to Operator X and the specific higher throughput and low latency, reliability communication services for chosen RSU X, Vehicle A, Vehicle B to report their sensor data are also required.

3. Operator X supplies required communication service for RSU X, Vehicle A, Vehicle B while others are supplied with normal communication service. LDM server continues to build LDM for downtown.

4. When delivering the LDM to Vehicle A, LDM Server asks Operator X to provide higher performance communication service to Vehicle A to support specific higher accuracy LDM for it. While other Vehicles in the area receive normal LDM.

5. When Vehicle B leaves downtown, it is no longer the key sensor supplier for downtown LDM construction. This information is notified to Operator X and from now on, the communication service for collected sensor data from Vehicle B is resumed to normal.

6. When Vehicle C is chosen as the key sensor data supplier for downtown LDM construction, the computing capability in Vehicle C can support it to share processed sensor data which does not need high throughput communication service. Considering LDM server demand and Operator X network status, the processed sensor data type is selected which need higher reliability, lower latency and middle throughput.

#### 5.29.1.3 Post-conditions

RSU X, Y can collect sensor data and deliver required whole situational awareness information to LDM server.

Vehicle A, B, C can deliver their sensor data in time and receive the downtown LDM according to the contract with MAPS.

The map company can choose key sensor data supplier and construct LDM, then provide different class map services to users.

The Operator X can provide different communication service on demand for V2X extended sensor use cases.

### 5.29.2 Potential Requirements

[PR.5. 29.2-001] The 3GPP system shall be able to expose the following services and capabilities to V2X applications, to support the V2X application offering:

- [PR.5.29.2-001a] The 3GPP system shall be able to support V2X applications to dynamically request specific quality of service of communication services and to dynamically request revocation of previous quality of service of communication services.

- [PR.5.29.2-001b] The 3GPP system shall be able to provide required quality of service to communication services on demand for different V2X applications.

## 5.30 Different QoS estimation for different V2X applications

### 5.30.1 Description

QoS estimation will help V2X applications e.g. automation driving, intelligent traffic system, to get the communication system connection capability in advance which is very important for them to compute and adjust in advance to right working mode to guarantee safety and service availability.

Different V2X application may need different QoS estimation content and accuracy. The more the content and the higher the accuracy, it costs more resource for QoS estimation function. And superfluous QoS estimation in one hand is not useful to V2X application, on the other hand it may impact other capabilities from whole system aspect because more collected information, more computing resources, more store resources are needed.

So, it is proposed to provide different QoS estimation information for different V2X applications.

#### 5.30.1.1 Pre-conditions

Vehicle A is a vehicle capable of supporting automated driving. It belongs to taxi company TT and is controlled by a V2X application of TT. The V2X application can reside either in Vehicle A and / or in the cloud of TT. Vehicles A can get communication service from the 3GPP system of Operator X which has a platinum level contract with TT to provide higher level QoS estimation e.g. support whole scenarios whole daytime of connection capability estimation with higher accuracy and more time advance value.

Vehicle B is one vehicle capable of supporting automated driving. It belongs to logistic company LL and is controlled by a V2X application of LL. The V2X application can reside either in Vehicle B and / or in the cloud of LL. Vehicles B also can get communication service from the 3GPP system of Operator X which has a golden level contract with LL to provide specific scenarios QoS estimation e.g. in highway scenario with whole daytime, in city scenario with specific time window.

#### 5.30.1.2 Service Flow

1. Vehicle A and Vehicle B both can achieve communication service from Operator X according to different contracts with their owners.

2. Vehicle A has an order from Hotel A to the airport beginning with 12:00am.

2.1The V2X application in Vehicle A subscribes to QoS estimation of the 3GPP system, and sends a estimation request with related supporting information asking whether it can provide specific QoS (e.g. data rate, latency, jitter, reliability) of communication service which is needed by its automation driving mode along planned vehicle route with associated timestamps from 12:00am.

2.2. The 3GPP system negotiates with the V2X application the parameters and mutual capabilities for estimation and evaluates and responds that it can predict that the required communication service for Vehicle A is going to be supplied during 12:00am~12:15am with associated a certain accuracy or probability and followed QoS estimation information (e.g. data rate, latency, jitter, reliability) will be delivered to Vehicle A for future area before 1.5km~10km distance in advance.

2.3. Vehicle A receives the estimation report and decides to enter automation driving mode. It picks passenger in Hotel A on time. During the journey to the airport, the QoS estimation information (e.g. data rate, latency, jitter, reliability) of the communication service for future area e.g. 1.5km~10km distance is continually delivered to the V2X application in Vehicle A.

2.4 Vehicle A may timely adjust its drive mode or automation level considering the QoS estimation information.

2.5 When Vehicle A arrives in airport, the application terminates the subscription to QoS estimation.

3. Vehicle B has a goods transportation task from city A to city B begin with 12:00am. Some of the road in the trajectory is city normal road and some is highway. The application in Vehicle B configures which QoS estimation information it need in different road when the QoS estimation is started.

3.1 The V2X application in Vehicle B subscribes to QoS estimation of the 3GPP system, and sends a estimation request with related supporting information asking whether it can provide specific QoS (e.g. latency, reliability) of communication service which is needed by its automation driving mode along the vehicle route with associated timestamps from city A to city B from 12:00am.

3.2 The 3GPP system negotiates with the V2X application the parameters and mutual capabilities for estimation and evaluates and responses that the required QoS with associated a certain accuracy or probability for communication service for Vehicle B can not be supplied from 12:00am in city road but in highway, it can be supplied.

3.3 Vehicle B receives the estimation response and decides not to enter automation driving mode. The journey is started, in the city road, Vehicle B is driven by Pilot and the QoS estimation (e.g. latency, reliability) of the communication service for future area e.g. from 1.5km~3km distance is continually delivered to the V2X application in Vehicle B. Before entering highway, the latest QoS estimation responses that the required QoS for automation driving is supported with a certain accuracy or probability, the Vehicle B adjust the driving mode to automation driving.

3.4 When Vehicle B arrives in destination, the application terminates the subscription to QoS estimation.

#### 5.30.1.3 Post-conditions

V2X application in vehicle A can receive timely QoS estimation information with associated accuracy or probability, so vehicle A can adjust its driving mode or automation level more safely and flexibly.

V2X application in vehicle B can receive QoS estimation required in advance in highway, so vehicle B can adjust its driving mode or automation level when it is in highway.

#### 5.30.2 Potential Requirements

[PR.5.30.2-001] The 3GPP system shall be able to expose the following services and capabilities to V2X applications, to support the V2X application to adjust its service offering:

- [PR.5.30.2-001a] The 3GPP system shall be able to provide different quality of service estimation information needed by different V2X applications.

- [PR.5.30.2-001b] The 3GPP system shall be able to support V2X applications to configure and negotiate quality of service estimation information and related supporting information to be provided by the V2X applications.

- [PR.5.30.2-001c] The 3GPP system shall be able to support V2X applications to request quality of service estimation information and to provide related supporting information to the 3GPP system.

- [PR.5.30.2-001d] The 3GPP system shall be able to provide V2X applications with quality of service estimation information according to the application’s configuration and request.

NOTE: The quality of service estimation information may contain detailed information depending on the application's request, e.g., on the accuracy of the estimation information.

- [PR.5.30.2-001e] The 3GPP system shall be able to support V2X applications to subscribe to quality of service estimation information, and to terminate the subscription to quality of service estimation information.

# 6 Considerations

## 6.1 Considerations on network slicing

As vehicles can drive without human involvement, human inside the vehicle will engage in other activities such as media consumption (e.g. web browsing, or video streaming). When safety-related V2X applications are concerned, consideration should be given to that the abnormal situation in other applications does not negatively affect the QoS of such V2X applications. When, different network slices are used to support different characteristic of applications for V2X and other applications, consideration should be given to that the isolation of network slice for V2X applications from other network slices is supported.

## 6.2 Considerations on deployment and mobility

Initially, the coverage area provided by NR radio access network will be smaller than that provided by E-UTRAN. To support service continuity and to meet QoS requirements for e.g. eMBB services, inter-system mobility will be used in general. However, performance achieved by the use of NR is expected to surpass the performance of E-UTRA, and some advanced V2X applications is supported only by NR. In this case, handover to E-UTRAN has impact on the proper operation of such advanced V2X applications. Thus, inter-system mobility needs to consider separate handling of V2X applications and other applications.

## 6.3 Considerations on relation to requirements of LTE V2X

All the requirements applied to LTE V2X, shown in [25], are applied to eV2X as well, unless otherwise stated.

# 7 Potential requirements

## 7.1 General

Different V2X scenarios require the transport of V2X messages with different performance requirements for the 3GPP system.

Vehicles Platooning enables the vehicles to dynamically form a platoon travelling together. All the UEs in the platoon obtain information from the leading vehicle to manage this platoon. These information allow the vehicles to drive closer (short time or distance inter-vehicle gap) than normal in a coordinated manner, going to the same direction and travelling together. These are expected to be a set of sophisticated application. The requirement on the communication latency is directly related to the assumed inter-vehicle gap (distance between successive vehicles and equivalent to vehicle density), which can be specified in meter or seconds.

Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video images among vehicles, road site units, devices’ of pedestrian and V2X application servers. The vehicles can increase the perception of their environment beyond of what their own sensors can detect and have a more broad and holistic view of the local situation. High data rate is one of the key characteristics.

Advanced driving enables semi-automated or full-automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or RSU shares its own perception data obtained from its local sensors with vehicles in proximity and that allows vehicles to synchronize and coordinate their trajectories or manoeuvres. Each vehicle shares its driving intention with vehicles in proximity, too. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency.

Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive by themselves or remote vehicles located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. Also, access to cloud-based back-end service platform can be considered for this use case group. High reliability and short low latency are the main requirements.

Vehicle quality of service support enables a V2X application to be notified of change of quality of service before actual change occurs and to enable the 3GPP System to modify the quality of service in line with V2X application’s quality of service needs. Based on the quality of service information, the V2X application can adapt behaviour to 3GPP System’s conditions. The benefit of this use case group are smoother user experience of service and increased safety.

## 7.2 Consolidated requirements

### 7.2.1 General requirements

Some requirements in this section are applicable to all V2X scenarios.

[CPR.G-001] The 3GPP system shall be able to control the communication range for a message based on the characteristic of the messages transmitted by a UE supporting V2X application.

[CPR.G-002] The 3GPP system shall be able to optimize the communication between UEs supporting V2X application belonging to the same group and in proximity.

[CPR.G-003] The 3GPP system shall be able to support the message transfer for group management operations as requested by the application layer.

[CPR.G-004] The 3GPP system shall be able to support message transfer among a group of UEs supporting V2X application.

[CPR.G-005] The 3GPP system shall be able to support message transfer between two UEs belonging to the same group of UEs supporting V2X application.

[CPR.G-006] The 3GPP system shall be able to support confidentiality and integrity of message transfer among a group of UEs supporting V2X application.

[CPR.G-007] The 3GPP system shall support relative lateral position accuracy of 0.1 m between UEs supporting V2X application.

[CPR.G-008] The 3GPP system shall support mechanisms to ensure sufficient reliability metrics are reached.

[CPR.G-009] The 3GPP system shall support high connection density for congested traffic.

NOTE: An example of estimate is for worst case US Freeway scenario that does not include arterial roads (i.e. onramps): 5 lanes in each direction or 10 lanes total per highway, for up to 3 highways intersecting = around 3,100 to 4,300 cars per square kilometer.

[CPR.G-010] The 3GPP system shall support efficient coordination of radio resources used for transport of V2X communications to maximize the utilisation of the available spectrum and to ensure the required reliability.

[CPR.G-011] The 3GPP system shall be able to control the UL and DL reliability of transport of V2X communications, depending on the requirement of V2X application

[CPR.G-012] Impact to E-UTRA(N) by UE supporting only NR based V2X communication shall be minimized.

[CPR.G-013] Impact to NR by UE supporting only E-UTRA based V2X communication shall be minimized.

[CPR.G-014] The 3GPP system shall be able to support message transfer between UEs or between a UE and a UE-type RSU, regardless of whether or not they are subscribers of the same PLMN supporting V2X communications. In case they are subscribers to different PLMNs, there shall be no service degradation of the message transfer.

[CPR.G-015] The 3GPP system shall be capable of supporting high reliability without requiring application-layer message retransmissions.

[CPR.G-016] The 3GPP system shall enable discovery and communication between UEs supporting the same V2X application.

[CPR.G-017] The 3GPP system shall be able to support for the operator to select which 3GPP RAT to use for a V2X application.

[CPR.G-018] The 3GPP system shall enable a UE supporting a V2X application to obtain network access via another UE supporting V2X application.

[CPR.G-019] The 3GPP system shall enable a UE supporting a V2X application to discover another UE supporting V2X application that can offer access to the network.

[CPR.G-020] The 3GPP system shall enable a UE supporting a V2X application to switch the network access from direct 3GPP connection to an indirect 3GPP connection via another UE supporting V2X application that is connected via 3GPP access to the 3GPP core network, and vice versa.

[CPR.G-021] The 3GPP system should provide integrity and confidentiality protection (end to end) for the network access traffic of a V2X UE via another such UE.

[CPR.G-022] The 3GPP system shall allow UEs supporting V2X application to use 5G RAT for direct communication when the UEs are not being serviced by a 5G cell.

[CPR.G-023] An RSU shall be able to communicate with up to 200 UEs supporting a V2X application.

[CPR.G-024] The 3GPP system shall support less than 5 ms communication latency for transport of V2V messages between two UEs supporting V2V applications, that are part of a group of UEs supporting V2Vapplications.

NOTE: The determination of group membership may be done at the upper layers and/or lower layers (application and/or Layer 2).

[CPR.G-025] The 3GPP system shall be able to support confidentiality and integrity of message transfer between a UE supporting V2X application and a V2X application server.

### 7.2.2 Requirements for platooning

[CPR.P-001] The 3GPP system shall be able to support up to 5 UEs for a group of UEs supporting V2X application.

[CPR.P-002] For Vehicle Platooning, the 3GPP system shall be able to support reliable V2V communications between a specific UE supporting V2X applications and up to 19 other UEs supporting V2X applications.

NOTE: For group of heavy goods vehicle platooning, the number of UEs in a platoon can be smaller, due to communication range, the length of truck, inter-truck distance, etc.

[CPR.P-003] The 3GPP system shall support relative longitudinal position accuracy of less than 0.5 m for UEs supporting V2X application for platooning in proximity.

Table 7.2.2-1 Performance requirements for platooning

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Communication scenario | | | | Payload (Bytes) | Tx rate (Message/ Sec) | Max end-to-end latency  (ms) | Reliabi-lity (%) | Data rate (Mbps) | Commu-nication  range (meters) |
| Section # | Description | | CPR # |
| 5.1 | Among a group of UEs (or two UEs) supporting V2X application | | [CPR.P-004] | 50-1200  (NOTE 1) | 30 | 10 |  |  |  |
| [CPR.P-005] | 300-400 | 30 | 25 | 90 |  |  |
| 5.2 | Between UE supporting V2X application and RSU via another UE supporting V2X application | | [CPR.P-006] | [50-1200] | 2 | 500 |  |  |  |
| 5.5 | Between UEs supporting V2X application | Driver control | [CPR.P-007] | 300-400  (NOTE 2) |  | 25 | 90 |  |  |
| Fully automated driving | [CPR.P-008] | 1200 |  | 10 | 99.99 |  | 80 |
| 5.12, 5.13 | Between UEs supporting V2X application | Conditionally automated driving | [CPR.P-009] | [6500] | 50 | [20] |  |  | [10] sec \* (max. relative speed) [m/s] |
| Highly/fully automated driving | [CPR.7.P-010] |  |  | [20] |  | [65] | [5] sec \* (max. relative speed) [m/s] |
| 5.12, 5.13 | Between UE supporting V2X application and RSU | Conditionally automated driving | [CPR.7.P-011] | [6000] | 50 | [20] |  |  | [10] sec \* (max. relative speed) [m/s] |
| Highly /Fully automated driving | [CPR.7.P-012] |  |  | [20] |  | [50] | [5] sec \* (max. relative speed) [m/s] |
| NOTE 1: This value does not including security related messages component.  NOTE 2: This value is applicable for both triggered and periodic transmission of data packets. | | | | | | | | | |

### 7.2.3 Requirements for advanced driving

Table 7.2.3-1 Performance requirements for advanced driving

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Communication scenario | | | | Payload (Bytes) | Tx rate (Message/Sec) | Max end-to-end latency  (ms) | Reliabi-lity (%) | Data rate (Mbps) | Commu-nication range (meters) |
| Section # | Description | | CPR # |
| 5.9 | Between UEs supporting V2X applications  Fully automated driving | | [CPR.A-001] | [2000] |  | [10] | [99.99] | [10] |  |
| 5.10, 5.11 | Between UEs supporting V2X application | Partially/conditional ly automated driving | [CPR.A-002] | [6500] | 10 | [100] |  |  | [10] sec \* (maximum relative speed) [m/s] |
| Highly automated driving | [CPR.A-003] |  |  | [100] |  | [53] | [5] sec \* (max. relative speed) [m/s] |
| 5.10, 5.11 | Between the UE supporting V2X application and the RSU | Partially/conditional ly automated driving | [CPR.A-004] | [6000] | 10 | [100] |  |  | [10] sec \* (max. relative speed) [m/s] |
| Highly automated driving | [CPR.A-005] |  |  | [100] |  | [50] | [5] sec \* (max. relative speed) [m/s] |
| 5.20 | Between UEs supporting V2X application  Fully automated driving | | [CPR.A-006 |  |  | [3] | [99.999] | [30] | [500] |
| 5.22 | Between RSU and UE supporting V2X application | | [CPR.A-007] | 450 | 50 |  |  | DL: [0.5] UL: [50] |  |
| 5.23 | Between UEs supporting V2X application | Driver control/  Limited automated driving | [CPR.A-008] | [300-400] |  | [25] | [90] |  |  |
| Full automated driving | [CPR.A-009] | [12000] |  | [10] | [99.99] |  |  |
| 5.25 | Between a UE supporting V2X application and a V2X application server | | [CPR.A-010] |  |  |  |  | UL: [10] |  |

### 7.2.4 Requirements for extended sensors

Table 7.2.4-1 Performance requirements for extended sensors

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Communication scenario | | | | Payload (Bytes) | Max end-to-end  latency  (ms) | Reliabi-lity (%) | Data rate (Mbps) | Communication range (meters) |
| Section # | Description | | CPR # |
| 5.3 | Between UEs supporting V2X application  Fully automated driving | | [CPR.E-001] |  | 10 | 95 | Peak data rate [25] |  |
| 5.6 | Between UEs supporting V2X application | Driver control | [CPR.E-002] | [1600] | 100 | 99 |  | 1000 |
| Fully automated driving | [CPR.E-003] |  | 3 | 99.999 |  | 200 |
| [CPR.E-004] |  | 10 | 99.99 |  | 500 |
| [CPR.E-005] |  | 50 | 99 |  | 1000 |
| [CPR.E-006] |  |  |  | 1000 | 50 |
| 5.16 | Between UEs supporting V2X application | Driver control/  Limited automated driving | [CPR.E-007] |  | [50] | 90 | [10] | [100] |
| Fully automated driving | [CPR.E-008] |  | [10] | 99.99 | [700] | [500] |

### 7.2.5 Requirements for remote driving

[CPR.R-001] The 3GPP system shall support user experienced data rate up to 1 Mbps at DL and 20 Mbps at UL for UE supporting V2X application between V2X application server and UE for an absolute speed of up to 250 km/h.

[CPR.R-002] The 3GPP system shall support ultra-high UL and DL reliability [99.999 or higher] % for UE supporting safety-related V2X application.

[CPR.R-003] The 3GPP system shall support end-to-end latency 5 ms between V2X application server and UE supporting safety-related V2X application for an absolute speed of up to 250 km/h.

Table 7.2.5-1 Performance requirements for remote driving

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Communication scenario | | | Payload (Bytes) | Max end-to-end  latency  (ms) | Reliabi-lity (%) | Data rate (Mbps) | Communication range (meters) |
| Section # | Description | CPR # |
| 5.21 | Between a UE supporting V2X application & V2X Application Server.  Driver Control | [CPR.R-004] |  | [20] | [99.999] | UL: 25  DL: 1 |  |

### 7.2.6 Requirements for vehicle quality of service support

[CPR.Q-001] The 3GPP system shall be able to provide V2X applications with estimated quality of service information, regardless of whether a UE related to the V2X application is in coverage of a 3GPP radio access network or not.

NOTE 1: This requirement may not be applicable all scenarios. For example, when quality of service information is generated in the 3GPP network and UE is out of coverage, V2X application cannot be provided with the quality of service information.

[CPR.Q-002] The 3GPP system shall be able to support efficient and secure mechanism to gather information (e.g. location information, reliability information, timing information, latency information, velocity information and so on.), which enables 3GPP system to support V2X application to adjust its service offering.

NOTE 2: It is FFS whether Minimization of Driving Test can support this requirement in consideration of the various velocity of vehicular environment.

[CPR.Q-003] The 3GPP system shall be able to minimize impact to system performance, while supporting a mechanism to gather information, which enables 3GPP system to support V2X application to adjust its service offering

[CPR.Q-004] The 3GPP system shall be able to support continuity of reporting estimated quality of service for a UE even when the PLMN serving the UE changes.

[CPR.Q-005] The 3GPP system shall be able to provide mechanisms to support the estimation of potential quality of service for a certain time period and a certain geographical location, with negotiated accuracy level to support V2X applications to adjust their service offerings.

[CPR.Q-006] The 3GPP system shall be able to provide mechanisms to support the provision of potential quality of service at a certain time period and a certain geographical location after informing the V2X applications with the quality of service information, the time period and the geographical location.

[CPR.Q-007] The 3GPP Core Network shall be able to provide a V2X application with recommendation of quality of service parameters that can be provisioned for connectivity services for a certain geographic area and a certain time.

[CPR.Q-008] The 3GPP network shall be able to negotiate alternative quality of service with the V2X application.

[CPR.Q-009] The 3GPP system shall be able to authenticate and authorize V2X application for accessing exposed services and capabilities of the 3GPP system to enable V2X application to adjust its service offering, based on gathered information.

[CPR.Q-010] The 3GPP system shall be able to provide authorized information to V2X application.

[CPR.Q-011] The 3GPP system shall be able to support V2X applications to request information on whether connectivity with specific quality of service can be provided in a certain geographical area and at a certain time

[CPR.Q-012] The 3GPP Core Network shall be able to support a V2X application to request reliable provision of connectivity with specific quality of service parameter for a certain geographic area and time.

[CPR.Q-013] The 3GPP system shall be able to provide V2X application with estimation on time and geographical information where the quality of service will be provided, when the 3GPP system provides the V2X applications with supported quality of service information.

[CPR.Q-014] The 3GPP system shall be able to provide V2X applications with information on whether requested connectivity with a certain quality of service can be provided in a certain geographical area at a certain time.

[CPR.Q-015] The 3GPP system shall be able to provide a standardized interface to V2X application, to support the V2X application to adjust its service offering.

[CPR.Q-016] The 3GPP Core Network shall be able to provide a V2X application with response on whether the request on reliable provision of connectivity service with specific quality of service parameter for a certain geographic area and a certain time is accepted or not.

[CPR.Q-017] The 3GPP system shall be able to notify V2X applications with updated estimation on the availability or unavailability of quality of service that can be provided within a certain geographic area, at least a certain amount of time before when the actual change occurs.

[CPR.Q-018] The 3GPP network shall notify a V2X application that the current quality of service of a UE’s ongoing communication might change indicating the specific period of time and/or geographical area it applies.

[CPR.Q-019] The 3GPP system shall be able to provide V2X applications with updated quality of service information within the list of quality of service previously provided by the V2X application, when the quality of service of the UE’s ongoing communication changes.

[CPR.Q-020] The 3GPP system shall be able to provide V2X applications with updated estimation on the quality of service that can be provided within a certain geographic area, at least a certain amount of time before when the actual change of quality of service occurs e.g. due to change of network condition or radio condition.

[CPR.Q-021] The 3GPP network shall be able to notify a V2X application when it estimates that the quality of service of a UE’s ongoing communication might need to be downgraded compared to the currently agreed quality of service e.g. due to expected bad network conditions, change of radio technology, radio congestion.

[CPR.Q-022] The 3GPP network shall be able to notify a V2X application when it estimates that the quality of service can be upgraded compared to the currently agreed quality of service of a UE’s ongoing communication e.g. due to expected improved network conditions, change of radio technology, less cell occupation.

[CPR.Q-023] The 3GPP system shall be able to support V2X applications to request revocation of the connectivity with previous quality of service parameters.

[CPR.Q-024] The 3GPP system shall be able to request V2X applications provide related supporting information for quality of service estimation.

NOTE3: the related supporting information provided by V2X applications may be path route priority, vehicle priority, vehicle automatic level etc.

[CPR.Q-025] The 3GPP system shall be able to provide V2X applications with quality of service estimation information according to the application’s configuration and request.

NOTE4: The quality of service estimation information may contain detailed information depending on the application’s request, e.g., on the accuracy of the estimation information.

# 8 Conclusion and recommendations

This document analyses a number of use cases of V2X for both safety use and non-safety use which the prior work on LTE support for V2X services [32] does not cover or is not able to support. This document also analyses a number of use cases that will be needed for interaction between V2X application and 3GPP system in relation to quality of service to support good V2X user experience of service and increased safety. The resulting potential requirements have been consolidated in clause 7 of the TR.

It is recommended that the consolidated potential requirements identified in this TR are considered as the basis of normative requirements in order to better serve the V2X applications safety needs.

Annex A:  
Mapping of use cases to use case group

Table A-1: Mapping of use cases to use case group

|  |  |  |
| --- | --- | --- |
| Use case group | Section number | Use case name |
| Platooning | 5.1 | eV2X support for Vehicle Platooning |
| 5.2 | Information exchange within platoon |
| 5.5 | Automated Cooperative Driving for Short distance Grouping |
| 5.12 | Information sharing for limited automated platooning |
| 5.13 | Information sharing for full automated platooning |
| 5.17 | Changing Driving-Mode |
| Advanced Driving | 5.9 | Cooperative Collision Avoidance (CoCA) |
| 5.10 | Information sharing for limited automated driving |
| 5.11 | Information sharing for full automated driving |
| 5.20 | Emergency Trajectory Alignment |
| 5.22 | Intersection Safety Information Provisioning for Urban Driving |
| 5.23 | Cooperative lane change (CLC) of automated vehicles |
| 5.25 | 3D video composition for V2X scenario |
| Remote driving | 5.4 | eV2X support for Remote Driving |
| 5.21 | Teleoperated Support (TeSo) |
| Extended Sensor | 5.3 | Automotive: Sensor and State Map Sharing |
| 5.6 | Collective Perception of Environment |
| 5.16 | Video data sharing for automated Driving |
| General | 5.7 | Communication between vehicles of different 3GPP RATs |
| 5.8 | Multi-PLMN environment |
| 5.15 | Use case on Multi-RAT |
| 5.19 | Use case out of 5G coverage |
| 5.14 | Dynamic Ride Sharing |
| 5.18 | Tethering via Vehicle |
| 5.24 | Proposal for secure software update for electronic control unit |
| Vehicle quality of service support | 5.26 | QoS aspect of vehicles platooning |
| 5.27 | QoS aspects of advanced driving |
| 5.28 | QoS aspects of remote driving |
| 5.29 | QoS Aspect for extended sensor |
| 5.30 | Different QoS estimation for different V2X applications |

Annex B:  
Mapping table between PRs and CPRs

Table B-1 Mapping between CPRs and PRs

|  |  |
| --- | --- |
| CPR # | PR # |
| CPR.G-001 | [PR.5.1-001] |
| CPR.G-002 | [PR.5.1-003] |
| CPR.G-003 | [PR.5.1-005] |
| CPR.G-004 | [PR.5.1-007] |
| CPR.G-005 | [PR.5.1-008] |
| CPR.G-006 | [PR.5.1-009] |
| CPR.G-007 | [PR.5.5-007] |
| CPR.G-008 | [PR.5.5-009] |
| CPR.G-009 | [PR.5.5-010] |
| CPR.G-010 | [PR.5.3-004] |
| CPR.G-011 | [PR.5.4-002] |
| CPR.G-012 | [PR.5.7-002] |
| CPR.G-013 | [PR.5.7-003] |
| CPR.G-014 | [PR.5.8-001] |
| CPR.G-015 | [PR.5.10-008] |
| CPR.G-016 | [PR.5.14-001]  [PR.5.14-002] |
| CPR.G-017 | [PR.5.15-001] |
| CPR.G-018 | [PR.5.18-001] |
| CPR.G-019 | [PR.5.18-002] |
| CPR.G-020 | [PR.5.18-003] |
| CPR.G-021 | [PR.5.18-004] |
| CPR.G-022 | [PR.5.19-001] |
| CPR.G-023 | [PR.5.22-002] |
| CPR.G-024 | [PR.5.5-003a] |
| CPR.G-025 | [PR.5.24-001] |
| CPR.P-001 | [PR.5.1-004] |
| CPR.P-002 | [PR.5.17-001] |
| CPR.P-003 | [PR.5.5-008] |
| CPR.P-004 | [PR.5.1-002]  [PR.5.1-006]  [PR.5.1-010]  [PR.5.1-011] |
| CPR.P-005 | [PR.5.1-002]  [PR.5.1-006]  [PR.5.1-012]  [PR.5.1-013]  [PR.5.1-014] |
| CPR.P-006 | [PR.5.2-001]  [PR.5.2-002]  [PR.5.2-003] |
| CPR.P-007 | [PR.5.5-001]  [PR.5.5-002]  [PR.5.5-003] |
| CPR.P-008 | [PR.5.5-004]  [PR.5.5-005]  [PR.5.5-006] |
| CPR.P-009 | [PR.5.12-003]  [PR.5.12-005]  [PR.5.12-006]  [PR.5.12-009] |
| CPR.P-010 | [PR.5.13-001]  [PR.5.13-003]  [PR.5.13-006] |
| CPR.P-011 | [PR.5.12-004]  [PR.5.12-007]  [PR.5.12-005]  [PR.5.12-009] |
| CPR.P-012 | [PR.5.13-002]  [PR.5.13-006]  [PR.5.13-004] |
| CPR.A-001 | [PR.5.9-001]  [PR.5.9-002] |
| CPR.A-002 | [PR.5.10-001]  [PR.5.10-003]  [PR.5.10-006]  [PR.5.10-009]  [PR.5.10-004]  [PR.5.10-005] |
| CPR.A-003 | [PR.5.11-001]  [PR.5.11-003]  [PR.5.11-006] |
| CPR.A-004 | [PR.5.10-002]  [PR.5.10-004]  [PR.5.10-007]  [PR.5.10-009]  [PR.5.10-005] |
| CPR.A-005 | [PR.5.11-002],  [PR.5.11-004],  [PR.5.11-006], |
| CPR.A-006 | [PR.5.20-001] |
| CPR.A-007 | [PR.5.22-003]  [PR.5.22-001] |
| CPR.A-008 | [PR.5.23-001] |
| CPR.A-009 | [PR.5.23-003] |
| CPR.A-010 | [PR.5.25-002] |
| CPR.E-001 | [PR.5.3-001]  [PR.5.3-002]  [PR.5.3-003] |
| CPR.E-002 | [PR.5.6-001]  [PR.5.6-002]  [PR.5.6-003] |
| CPR.E-003 | [PR.5.6-004] |
| CPR.E-004 | [PR.5.6-005] |
| CPR.E-005 | [PR.5.6-006] |
| CPR.E-006 | [PR.5.6-007] |
| CPR.E-007 | [PR.5.16-001] |
| CPR.E-008 | [PR.5.16-002] |
| CPR.R-001 | [PR.5.4-001] |
| CPR.R-002 | [PR.5.4-003] |
| CPR.R-003 | [PR.5.4-004] |
| CPR.R-004 | [PR.5.21-001] |
| CPR.Q-001 | [PR.5.26.2-001] |
| CPR.Q-002 | [PR.5.27.5-001] |
| CPR.Q-003 | [PR.5.27.5-003] |
| CPR.Q-004 | [PR.5.27.6-001] |
| CPR.Q-005 | [PR.5.27.7-001] |
| CPR.Q-006 | [PR.5.27.7-002]  [PR.5.28.2-002] |
| CPR.Q-007 | [PR.5.28.2-001g] |
| CPR.Q-008 | [PR.5.28.1-002]  [PR.5.27.5-002] |
| CPR.Q-009 | [PR.5.27.3-001]  [PR.5.27.3-002] |
| CPR.Q-010 | [PR.5.27.3-003] |
| CPR.Q-011 | [PR.5.27.2-001a]  [PR.5.27.2-001c]  [PR.5.28.2-001a]  [PR.5.28.2-001c] |
| CPR.Q-012 | [PR.5.28.2-001e] |
| CPR.Q-013 | [PR.5.26.2-003]  [PR.5.26.2-004] |
| CPR.Q-014 | [PR.5.27.2-001b]  [PR.5.27.2-001d] [PR.5.28.2-001b]  [PR.5.28.2-001d] |
| CPR.Q-015 | [PR.5.28.2-001] |
| CPR.Q-016 | [PR.5.28.2-001f] |
| CPR.Q-017 | [PR.5.27.4-001b] |
| CPR.Q-018 | [PR.5.28.1-003] |
| CPR.Q-019 | [PR.5.26.2-002] |
| CPR.Q-020 | [PR.5.27.4-001d] |
| CPR.Q-021 | [PR.5.28.1-001] |
| CPR.Q-022 | [PR.5.28.1-004] |
| CPR.Q-023 | [PR.5.29.2-001a] |
| CPR.Q-024 | [PR.5.30.2-001b]  [PR.5.30.2-001c] |
| CPR.Q-025 | [PR.5.30.2-001d]  [PR.5.30.2-001a] |

Annex C:  
Other considered use cases

## C.1 Interoperability with other V2X schemes

### C.1.1 Description

#### C.1.1.1 General

As the automotive industry already started adopting non-3GPP V2X technologies (e.g., 760 MHz ITS Connect in Japan, 5.9 GHz DSRC in the US, and 5.9 GHz ITS-G5 in Europe), it is essential that vehicles with eV2X capability are also interoperable with “legacy” vehicles with only a current non-3GPP V2X capability (cf. [20]). This being “essential” comes from the understanding that “*realizing the full extent of benefits from cooperative driving depends on the availability of a critical mass of capable and compatible vehicles on the road*” and that “*the long product lifecycle in the automotive market (i.e., 10 – 14 years)*” (cf. [20]).

As the objective of the WID already suggests, interoperability with non-3GPP V2X technologies should be ensured at the application level, understanding NR could be quite different from e.g. IEEE 802.11p.

An interpretation of this “interoperability” is as follows. Considering early adoption of non-3GPP V2X technologies in some regions, for years to come there exist vehicles with only a non-3GPP V2X device. In this circumstance, some V2X messages (e.g., Basic Safety Messages or Cooperative Awareness Messages / Decentralized Environmental Notification) are to be transmitted using non-3GPP V2X technologies. eV2X capability is to be used to convey at least additional V2X messages (e.g., high-resolution perception data and/or detailed planned trajectory) to complement non-3GPP V2X technologies. In this way, all vehicles with V2X capability, whether having an eV2X UE or not, can make the best use of their outfit.

#### C.1.1.2 Pre-conditions

1. Vehicles A and B are equipped with both an eV2X UE and a non-3GPP V2X device. Vehicle C is equipped with only a non-3GPP V2X device. Vehicles A, B, and C are in the communication range.

#### C.1.1.3 Service flows

1. Vehicles A and B share their Basic Safety Messages or Cooperative Awareness Messages / Decentralized Environmental Notification (and their detected objects and/or coarse driving intention) with Vehicle C using the non-3GPP V2X technology, and vice versa.

2. Vehicle C uses the above information received from Vehicles A and B for its driving.

3. Vehicle A shares its high-resolution perception data and/or detailed planned trajectory with Vehicle B using the eV2X technology, and vice versa. Vehicles A and B obtain information of surrounding environments that cannot be obtained only from their local sensors.

4. Vehicle A combines the above information received from Vehicles B and C, and uses it for its driving. The same applies to Vehicle B.

#### C.1.1.4 Post-conditions

1. Road safety and traffic efficiency is improved. For Vehicles A and B, having an eV2X capability as well further improves those.

Annex D:  
Change history

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |  |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/comment | New version | |
| 2016-05 | SA1#74 |  |  |  |  | Skeleton | 0.0.0 | |
| 2016-05 | SA1#74 |  |  |  |  | Addition of contents agreed at SA1#74 | 0.1.0 | |
| 2016-08 | SA1#75 |  |  |  |  | Addition of contents agreed at SA1#75 | 0.2.0 | |
| 2016-09 | SA#73 |  |  |  |  | Clean-up for presentation to SA | 1.0.0 | |
| 2016-11 | SA1#76 |  |  |  |  | Addition of contents agreed at SA1#76 | 1.1.0 | |
| 2016-12 | SA#74 |  |  |  |  | Clean-up for presentation for approval to SA | 2.0.0 | |
| 2016-12 | SA#74 |  |  |  |  | Raised to version 15.0.0 following SA's Approval | 15.0.0 | |
| 2017-03 | SA#75 | SP-170168 | 0001 | 1 | D | Correction of typos, editorial corrections to eV2X | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0010 | 1 | B | Enhancement of use case 5.5 and 5.16 | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0014 | 1 | F | Remove requirement implying that NR-based Prose needs to support LTE-based Prose | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0003 | 1 | F | Alignment and correction of payload value in the Cooperative collision avoidance (CoCA) use case. | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0009 | 1 | F | Inclusion of assumed inter-vehicle gaps in CPR tables | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0011 | 2 | F | Connection density for eV2X | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0008 | 2 | F | Clarification regarding radio latency vs. end-to-end latency | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0007 | 4 | F | Clarification regarding Level of Automation | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0004 | 2 | F | Missing consolidated potential requirements for eV2X | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0005 | 2 | F | Clarification on PR and CPR | 15.1.0 | |
| 2017-03 | SA#75 | SP-170168 | 0002 | 4 | C | Clarify use case associated to platooning size in section 7 2 2 | 15.1.0 | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | | | | | | |
| **TSG SA#** | **SA Doc.** | **SA1 Doc** | **Spec** | **CR** | **Rev** | **Rel** | **Cat** | **Subject/Comment** | **Old** | **New** | **WI** |  |
| [SP-80](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | SP-180309 | [S1-181350](http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_82_Dubrovnik/Docs/S1-181350.zip) | [22.886](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | 0022 | 1 | [Rel-15](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=190) | F | Update the note in the RSU definition | 15.1.0 | 15.2.0 | [FS\_eV2X](http://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=720003) |  |
| [SP-80](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | SP-180356 | [S1-181724](http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_82_Dubrovnik/Docs/S1-181724.zip) | [22.886](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | 0016 | 2 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | B | Assistance to remote driving application3 | 15.1.0 | 160.0 | [FS\_V2XIMP](http://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=790002) |  |
| [SP-80](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | SP-180356 | [S1-181727](http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_82_Dubrovnik/Docs/S1-181727.zip) | [22.886](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | 0017 | 2 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | B | Adjustment of configuration of Platooning Application3 | 15.1.0 | 160.0 | [FS\_V2XIMP](http://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=790002) |  |
| [SP-80](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | SP-180356 | [S1-181728](http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_82_Dubrovnik/Docs/S1-181728.zip) | [22.886](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | 0018 | 3 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | B | Adjustment of Autonomous Driving Level - General aspect | 15.1.0 | 160.0 | [FS\_V2XIMP](http://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=790002) |  |
| [SP-80](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | SP-180356 | [S1-181729](http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_82_Dubrovnik/Docs/S1-181729.zip) | [22.886](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | 0019 | 3 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | B | Adjustment of Autonomous Driving Level - assistance aspect | 15.1.0 | 160.0 | [FS\_V2XIMP](http://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=790002) |  |
| [SP-80](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | SP-180356 | [S1-181730](http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_82_Dubrovnik/Docs/S1-181730.zip) | [22.886](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | 0020 | 3 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | B | Adjustment of Autonomous Driving Level - other aspect | 15.1.0 | 160.0 | [FS\_V2XIMP](http://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=790002) |  |
| [SP-80](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | SP-180356 | [S1-181731](http://www.3gpp.org/ftp/tsg_sa/WG1_Serv/TSGS1_82_Dubrovnik/Docs/S1-181731.zip) | [22.886](http://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3108) | 0021 | 4 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | B | Notification of QoS Change for Remote Driving Application-clean | 15.1.0 | 160.0 | [FS\_V2XIMP](http://portal.3gpp.org/desktopmodules/WorkItem/WorkItemDetails.aspx?workitemId=790002) |  |
| SP-81 | SP-180755 | S1-182624 | 22.886 | 0030 | 1 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | A | SAE International's Levels of Automation reference link | 16.0.0 | 16.1.0 | FS\_eV2X |  |
| SP-81 | SP-180782 | S1-182511 | 22.886 | 0024 | 1 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | D | Correction to use cases | 16.0.0 | 16.1.0 | FS\_V2XIMP |  |
| SP-81 | SP-180782 | S1-182695 | 22.886 | 0028 | 2 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | B | QoS list to support V2X critical applications | 16.0.0 | 16.1.0 | FS\_V2XIMP |  |
| SP-81 | SP-180782 | S1-182734 | 22.886 | 0023 | 3 | [Rel-16](http://portal.3gpp.org/desktopmodules/Release/ReleaseDetails.aspx?releaseId=191) | F | Consolidated requirements for FS\_V2XIMP | 16.0.0 | 16.1.0 | FS\_V2XIMP |  |
| SP-81 | SP-180782 | S1-182735 | 22.886 | 0025 | 4 | Rel-16 | B | Different QoS estimation for different V2X applications | 16.0.0 | 16.1.0 | FS\_V2XIMP |  |
| SP-81 | SP-180782 | S1-182736 | 22.886 | 0026 | 3 | Rel-16 | B | QoS aspect for extended sensor | 16.0.0 | 16.1.0 | FS\_V2XIMP |  |
| SP-81 | SP-180782 | S1-182738 | 22.886 | 0027 | 2 | Rel-16 | F | Terminology clarification | 16.0.0 | 16.1.0 | FS\_V2XIMP |  |
| SP-81 | - | - | - | - |  |  |  | In v.16.1.0, the content of 5.29 was duplicated with the content of 5.30. The content of 5.29 has been replaced by content of 5.31, so the four aspects regarding QoS are now in 5.26, 5.27, 5.28 and 5.29. | 16.1.0 | 16.1.1 | - |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2018-12 | SP-82 | SP-181018 | 0031 | 1 | F | corrections to FS\_V2XIMP | 16.2.0 |
| 2018-12 | SP-82 | SP-181018 | 0032 | 1 | F | Supplementary consolidated requirements for FS\_V2XIMP | 16.2.0 |
| 2018-12 | SP-82 | SP-181018 | 0033 | 1 | F | Clarification on details of estimation information for different V2X applications | 16.2.0 |