BEFORE THE
U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
WASHINGTON, D.C. 20590

In the Matter of	)	
	)	
Framework for Automated Driving System Safety Principles	)	Docket No. NHTSA-2020-0106
	)	
	)	

COMMENTS OF THE 5G AUTOMOTIVE ASSOCIATION

The 5G Automotive Association ("5GAA") hereby submits comments in response to the *Advanced Notice of Proposed Rulemaking* ("*ANPRM*") issued by the National Highway Traffic Safety Administration ("NHTSA") seeking comment on the potential development of a framework of principles to govern the safe behavior of automated driving systems ("ADS").[1]

I. INTRODUCTION AND SUMMARY

5GAA is a multi-industry organization whose mission is to develop end-to-end connectivity solutions for intelligent transportation, future mobility systems, and smart cities.[2] Formed in 2016, 5GAA has quickly grown from its eight founding members to a global organization with more than 140 companies. Today, 5GAA's members include some of the most recognized leaders in the automotive, telecommunications, and technology industries.

5GAA commends NHTSA for seeking comment on the appropriate regulatory framework for principles governing ADS safety. The issuance of the *ANPRM* is particularly timely in light of the global

[1] U.S. Department of Transportation, National Highway Traffic Safety Administration, Framework for Automated Driving System Safety, 85 Fed. Reg. 78058, 78075 (Dec. 3, 2020).

[2] *See* 5GAA, https://5gaa.org (last visited Apr. 1, 2021). Visit https://5gaa.org/membership/our-members for a complete list of member companies.

market momentum for Cellular Vehicle-to-Everything ("C-V2X").[3] C-V2X is a state-of-the-art connected vehicle platform built on recent advancements in cellular technologies and earlier efforts to develop intelligent transportation systems ("ITS"). It leverages modern 4G LTE-Pro and 5G New Radio (NR) cellular protocols to allow vehicles to receive and transmit information about their internal and external environments. By marrying modern cellular technology with previous work on ITS, C-V2X can help unlock new and improved automotive safety applications, including ADS applications.

The global market momentum for C-V2X is accelerating at a rapid rate. Automakers are already deploying C-V2X-enabled vehicles in other parts of the world, and in countries where C-V2X is not already authorized, regulators are racing to modernize policies to accommodate this connected vehicle platform. Here in the United States, major automakers like the Ford Motor Company are raring to sell cars with C-V2X, and leading transportation authorities are deploying the technology along U.S. roadways.

Industry stakeholders are also collaborating on the continued evolution of C-V2X, including features that support more advanced driving use cases. As perception, planning, and control functionality improves, ADS systems will need to better understand and interact with the road environment (*i.e.*, improved sensing and transmitting capabilities). 5G-powered C-V2X can facilitate this understanding and

[3] C-V2X is comprised of two complementary communications modes for vehicular operations: direct (called PC5 in Third Generation Partnership Project ("3GPP") specifications) communications and network (called Uu in the 3GPP specifications) communications. Direct C-V2X communications enable (1) vehicle-to-vehicle communications, which are used to communicate safety information between nearby vehicles to improve traffic flow and prevent collisions; (2) vehicle-to-roadside infrastructure communications (*e.g.*, traffic signals, variable message signs, etc.), which are used to communicate safety and traffic information, prevent accidents associated with roadway conditions, and improve traffic efficiency; and (3) vehicle-to-pedestrian communications, which are expected to be used to communicate safety information between vehicles and other road users, such as pedestrians, bicyclists, scooter riders, etc., to prevent accidents. To augment these direct communications, C-V2X's network mode capabilities allow vehicles to communicate using cellular networks.

interaction. Cellular industry standards bodies already have incorporated C-V2X features into the most recent release of the 5G standard, and work is already underway to develop additional features for future 5G releases.

As NHTSA considers a framework of principles for ADS, it should recognize and embrace this global market momentum by prioritizing policies that promote continued C-V2X deployment and accelerated investment in this connected vehicle platform.

II. AUTOMAKERS ARE RARING TO LAUNCH C-V2X IN VEHICLES, AND NHTSA SHOULD EMBRACE POLICIES THAT ENCOURAGE AND PROMOTE THESE DEPLOYMENTS

In 2019, 5GAA described to the United States Department of Transportation the growing momentum for C-V2X.[4] This momentum was reflected in a series of technological and market developments contributing to the growing adoption of C-V2X and actions by regulators to modernize policies to accommodate this connected vehicle platform. In the time since that filing, the global adoption of C-V2X has grown exponentially as automakers, road operators, and technology companies move forward to bring this technology to travelers and other road users.

Automakers are now selling C-V2X-equipped vehicles in other regions of the world. General Motors launched C-V2X in its Buick line of vehicles in China last year.[5] Leveraging China's investment in

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[4] *See* Comments of the 5G Automotive Association, Docket No. DOT-OST-2018-0210, at 12-14 (Feb. 25, 2019).

[5] Press Release, General Motors, *Buick Revolutionizes GL8 MPV Family in China with Elevated Intelligent Driving Technology* (Dec. 10, 2020), https://media.gm.com/media/cn/en/gm/news.detail.html/content/Pages/news/cn/en/2020/Dec/1210-Buick.html; Press Release, Buick, *Buick Debuts V2X Technology and Launches Refreshed GL6 MPV in China* (Nov. 20, 2020), https://media.buick.com/media/cn/en/buick/home.detail.html/content/Pages/news/cn/en/2020/Nov/1120-Buick.html; Press Release, Qualcomm, *General Motors and Qualcomm Extend Long-Standing Relationship to Transform Next Generation Vehicles* (Jan. 26, 2021), https://www.qualcomm.com/news/releases/2021/01/26/general-motors-and-qualcomm-extend-long-standing-relationship-transform.

C-V2X roadside infrastructure, Ford recently launched C-V2X in two of its flagship vehicles—the Explorer and Edge Plus—offering game-changing vehicle-to-infrastructure services.[6] And a host of Chinese automakers including FAW Car Company, GAC Group, and SAIC Motor Corporation also have launched C-V2X in their vehicle fleets within the past year.[7]

Car manufacturers also continue to announce future C-V2X launches at an increasingly frequent rate. Ford recently revealed plans to incorporate this technology into future versions of its Mustang Mach-E SUV sold in China.[8] Chinese automaker Geely also is launching C-V2X in its vehicles later this year,[9] and over a dozen other Chinese auto manufacturers have affirmed similar plans to include this technology in new vehicles introduced over the coming months and years.[10]

The momentum for C-V2X deployment is evident in the United States as well. Most notably, major automakers like Ford are raring to put C-V2X in consumer vehicles. These deployments will bring state-of-the-art C-V2X safety and efficiency applications to U.S. consumers and travelers, and spur other automakers to make similar deployments.

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[6] Kyle Johnson, *Ford Launches V2I Technologies in China*, The News Wheel, Jan. 15, 2021, https://thenewswheel.com/ford-v2i-technologies-debut-china.

[7] *See Hongqi's C-V2X-enabled E-HS9 BEV hits the market*, Gasgoo, Dec. 6, 2020, http://autonews.gasgoo.com/china_news/70017798.html; 红旗E-HS9发布 搭载高通C-V2X解决方案, 新华网, Dec. 4, 2020, http://www.xinhuanet.com/tech/2020-12/04/c_1126822543.htm.

[8] Press Release, Ford, *Ford to Manufacture Mustang Mach-E in China for Local Customers* (Jan. 27, 2021), https://media.ford.com/content/fordmedia/fna/us/en/news/2021/01/27/ford-manufacture-mustang-mach-e-china.html.

[9] Press Release, Geely, *Geely to Collaborate with Qualcomm and Gosuncn on Mass-Produced 5G and C-V2X-Enabled Vehicles* (Feb. 26, 2019), http://global.geely.com/media-center/news/geely-to-collaborate-with-qualcomm-and-gosuncn-on-mass-produced-5g-and-c-v2x-enabled-vehicles.

[10] *See* Press Release, Qualcomm, *C-V2X global market momentum continues to accelerate* (Jan. 27, 2021), https://www.qualcomm.com/news/onq/2021/01/27/c-v2x-global-market-momentum-continues-accelerate.

Audi deployed C-V2X in vehicles last year to demonstrate the technology's ability to improve work zone and intersection safety as part of a project with the Virginia Department of Transportation and 5GAA members American Tower Corporation and Commsignia.[11] Building on the success of that project, Audi recently announced another collaborative venture—this time with 5GAA members Applied Information and Temple—to demonstrate C-V2X's ability to improve safety in and around school zones and bus stops.[12] This latest project will leverage C-V2X smart infrastructure deployed in the vicinity of Applied Information's Infrastructure Automotive Technology Laboratory, a new facility for developing and testing the latest C-V2X applications.

Nearly every major automaker in the world has conducted rigorous testing of C-V2X performance by this point. General Motors, Ford, Nissan, Hyundai, and Qualcomm recently concluded one such demonstration at Michigan's Crash Avoidance Metrics Partners LLC ("CAMP") facility.[13] After conducting a battery of tests to demonstrate C-V2X performance, the study concluded, among other things, that the technology works reliably in congested environments.[14]

In response to this market momentum, federal, state, and local transportation agencies are accelerating investments in C-V2X-powered smart infrastructure along America's roads. The Federal

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[11] Press Release, Audi, *Audi collaborates to deploy C-V2X communication technology on Virginia roadways* (Sept. 29, 2020), https://media.audiusa.com/en-us/releases/437.

[12] Press Release, Audi, *Audi*, *Applied Information and Temple launch C-V2X school safety development program in Georgia* (Oct. 27, 2020), https://media.audiusa.com/en-us/releases/446.

[13] Crash Avoidance Metrics Partnership, *Cellular V2X Device-to-Device Communication (C-V2X) Project*, https://www.campllc.org/project-cellular-v2x-device-to-device-communication-c-v2x (last visited Apr. 1, 2021).

[14] Press Release, Qualcomm, *C-V2X performance under congested conditions* (Sept. 9, 2020), https://www.qualcomm.com/news/onq/2020/09/09/c-v2x-performance-under-congested-conditions (noting that the study concluded that C-V2X technology shows good communication performance and operates reliably in controlled, mixed real-world traffic and congestions scenarios as dense as 250 vehicles on a 300m stretch of roadway).

Highway Administration is working with the Hawaii Department of Transportation through its Advanced Transportation and Congestion Management Technologies Deployment Program[15] to implement C-V2X along critical traffic corridors in Honolulu.[16] And in addition to the previously-referenced deployments in Virginia, state and local road operators are implementing C-V2X along roadways in Georgia, Michigan, Texas, and Colorado.

Technology and telecommunications companies are bringing C-V2X products to market at an increasing rate. Over sixty C-V2X products are already available in the market, from modules to chipsets to software.[17] And just earlier this year, leading software developers Commsignia, COHDA Wireless, and Marben Products each launched production-ready C-V2X software solutions.[18]

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[15] The Advanced Transportation and Congestion Management Technologies Deployment Program awards competitive grants for the development of model deployment sites for large scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment. *See* U.S. Department of Transportation, Federal Highway Administration, *Fixing America's Surface Transportation Act or "FAST Act"*, https://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm.

[16] U.S. Department of Transportation, Federal Highway Administration, *Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program*, https://ops.fhwa.dot.gov/fastact/atcmtd/2019/awards/factsheet/pdf/hawaii.pdf.

[17] 5G Automotive Association, Technical Report, *5G Automotive Association e.V., Working Group 5, List of C-V2X Devices*, https://5gaa.org/wp-content/uploads/2020/11/5GAA_List-of-C-V2X-Devices.pdf.

[18] Press Release, Commsignia, *Commsignia's High Performing V2X Software Stack Available with Snapdragon Automotive 5G and 4G Platforms* (Feb. 9, 2021), http://www.itnewsonline.com/PRNewswire/Commsignias-High-Performing-V2X-Software-Stack-Available-with-Snapdragon-Automotive-5G-and-4G-Platforms/731780; Press Release, *Cohda Wireless, Cohda Wireless Delivers New Global C-V2X Turnkey Solution for Road Safety & Traffic Efficiency with Integration On Qualcomm Snapdragon Automotive 5G & 4G Platforms* (Feb. 9, 2021), https://cohdawireless.com/cohda-wireless-delivers-new-global-c-v2x-turnkey-solution-for-road-safety-traffic-efficiency-with-integration-on-qualcomm-snapdragon-automotive-5g-4g-platforms; Press Release, Marben Products, *Marben Completes Validation of C-V2X Stack and Applications on Qualcomm Snapdragon Automotive 4G and 5G Platforms to Accelerate Commercialization by Global Automakers* (Feb. 18, 2021), https://www.prweb.com/releases/marben_completes_validation_of_c_v2x_stack_and_applications_on_qualcomm_snapdragon_automotive_4g_and_5g_platforms_to_accelerate_commercialization_by_global_automakers/prweb17734148.htm.

It is thus evident that C-V2X is gaining momentum at a rapid pace. C-V2X vehicular deployments are being planned and launched in the United States and internationally, leading transportation authorities are deploying this technology along U.S. roadways, and telecommunications and technology companies are introducing products that support the continued growth of the C-V2X ecosystem. These actions have kickstarted the virtuous cycle of C-V2X investment, with each event incentivizing other stakeholders to invest in C-V2X. NHTSA should embrace this market momentum. C-V2X's ability to support ADS safety applications directly correlates to the percentage of vehicles equipped with this technology platform—as more vehicular deployments are launched, the effectiveness of C-V2X in supporting ADS safety also increases. NHTSA should thus pursue policies that promote and accelerate this market momentum for C-V2X deployment as part of any regulatory framework adopted for ADS safety.

III. IN THE DAWN OF THE 5G ERA C-V2X IS EVOLVING TO MEET THE MORE DEMANDING SAFETY REQUIREMENTS OF AUTOMATED DRIVING SYSTEMS, AND NHTSA'S POLICIES SHOULD ENCOURAGE THIS PROGRESS

Leveraging ongoing advancements in the cellular industry, automotive and telecommunications stakeholders are collaborating to enhance the performance of C-V2X to meet the more demanding safety requirements of ADS. As perception, planning, and control functionality improves, ADS systems will need to better understand and interact with the road environment through improved sensing and transmitting capabilities. 5G-powered C-V2X can facilitate this understanding and interaction. With extreme throughput, low latency, and enhanced reliability, 5G-powered C-V2X will allow ADS systems to receive and share increasingly detailed, real-time data with other vehicles, pedestrians, and road infrastructure.

Industry standards bodies are quickly identifying technical requirements and implementation details to accelerate C-V2X's evolution to 5G. Just last year, 3GPP—the world's preeminent standards body for cellular technologies—incorporated C-V2X features into the Release 16 standard for 5G NR.[19] These new features support advanced applications such as extended sensor sharing and trajectory/intent sharing. Extended sensor sharing applications will enable real-time exchange of data gathered through local sensors, allowing vehicles to "see" through other vehicles, around turns, and in other limited visibility traffic scenarios. Trajectory and intent sharing will allow vehicles to do what one might imagine: share trajectory data and information about future intent, enabling ADS systems to more easily negotiate lane changes at highway speeds, traffic circles, and intersection crossings. And 5G-powered C-V2X is not stopping there—standards work is also already underway on additional C-V2X features as part of the 3GPP Release 17 for 5G NR.

Automotive, telecommunications, and technology stakeholders are also collaborating within 5GAA to accelerate the integration of 5G-powered C-V2X with ADS applications. As summarized in the accompanying report provided as Appendix A, 5GAA members expect that ADS applications supported by 5G C-V2X will be available by 2024. 5GAA has also released two separate technical reports, included as Appendix B and Appendix C, that summarize C-V2X use cases—including ADS applications—and their service level requirements. Compiled within 5GAA's cross-industry collaborative forum, these use cases and timelines represent automotive and telecommunications stakeholders' unified view of C-V2X-enabled ADS applications that will be introduced in the coming years.

In sum, C-V2X is quickly evolving to support the more demanding safety requirements of ADS systems. This evolution is being driven in technical standards bodies while industry stakeholders chart a

[19] 3GPP develops specifications that are codified as accredited standards by the Alliance for Telecommunications Industry Solutions ("ATIS") in the United States and by other "Organizational Partners" in different geographical regions. *See* 3GPP, Partners, http://www.3gpp.org/about-3gpp/partners (last visited Apr. 1, 2021) for a complete list of the accredited Standards Defining Organizations ("SDOs") around the world. Any references to 3GPP herein indicate any relevant 3GPP specification adopted as a standard by the Organizational Partners.

roadmap for the integration of C-V2X with ADS. As NHTSA considers the proper regulatory framework for ADS, it should pursue policies that encourage continued investment in C-V2X advancements.

IV. CONCLUSION

Ongoing collaboration between automotive, telecommunications, and technology stakeholders is accelerating the development, deployment, and evolution of C-V2X. As NHTSA considers a framework of principles to govern the safe behavior of ADS, it should recognize and embrace this global market momentum for C-V2X by prioritizing policies that promote continued deployment of and accelerated investment in this connected vehicle platform.

Respectfully submitted,

5G AUTOMOTIVE ASSOCIATION

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APPENDIX A

A visionary roadmap for advanced driving use cases, connectivity technologies, and radio spectrum needs

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Executive Summary

With this white paper, the 5G Automotive Association (5GAA) presents the results of its studies relating to the evolution of automotive connectivity for the purposes of enhanced road safety, improved traffic efficiency, greener environmental impact, and more comfortable driving.

Recognising the roadmap publications of other organisations, such as ACEA[1] and ERTRAC[2] in Europe, AASHTO TSMO guidance[3] and US DOT Strategic Plan[4], and the National Vision on Intelligent Connected Vehicles in China[5], this 5GAA white paper sets out a consolidated view of the automotive and telecommunications industries on the evolution of communication technologies, their application to automotive connectivity, and the deployment of advanced driving use cases up to 2030, which include advanced safety and automated driving (AD).

1 https://www.acea.be/publications/article/roadmap-for-the-deployment-of-automated-driving-in-the-european-union
2 https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf
3 http://www.aashtotsmoguidance.org/
4 https://www.its.dot.gov/stratplan2020/ITSJPO_StrategicPlan_2020-2025.pdf
5 Innovation and Development Strategy for Intelligent and Connected Vehicle (Final Release Feb. 2020) http://www.tzxm.gov.cn/flfg/regulations/202002/t20200226_13154.html

Many so-called day-1 basic safety use cases have been widely analysed in the past, and several of these have already been deployed. This white paper focuses on advanced driving use cases which pave the way to automated driving, and thereby contribute to global safety and traffic efficiency goals, as well as environmental benefits for citizens and consumers.

5GAA has identified the most promising advanced driving use cases such as Cooperative Manoeuvres and Sensor Sharing, in conjunction with the adoption of Cellular Vehicle-To-Everything (C-V2X) standards as well as availability of required technologies and devices, i.e. on-board units (OBUs), road-side units (RSUs), and smartphones, integrating the latest chipsets and modules. The market trajectory of the identified use cases is described along with the expected timeline for their mass market deployment.

5GAA notes that many advanced driving use cases will require 5G-V2X radios. 5G-V2X is considered for advanced driving and LTE-V2X is considered for basic safety use cases, each encompassing both network and direct communications. Mobile network operators around the world have started to deploy 5G, building on current 4G networks. In the meantime, the planned releases of the 3GPP standards include new features for direct communications, such as low power consumption in handheld devices, enabling additional use cases. The roadmap also accounts for the work currently undertaken on the upper application layers (e.g. message types and protocols), as well as equipment availability, testing and interoperability. Finally, our findings show that some advanced driving use cases will require direct communication for their implementation.

In the next two to three years, 5GAA expects to see mass deployment of traffic efficiency and basic safety V2X use cases around the world. From 2024 onwards, we further anticipate the large-scale introduction of advanced safety and automated driving use cases supported by C-V2X. Additional connected automated driving functionalities are expected to be introduced starting in 2026.

Considering the current 3GPP releases roadmap and supply chain readiness, the 5GAA technology roadmap is summarised in Figure 1.

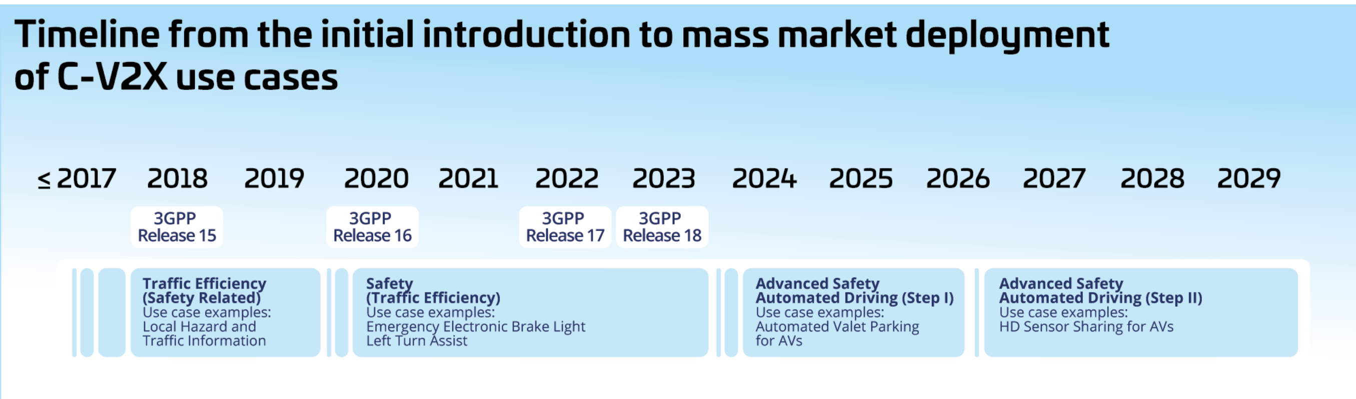


Figure 1: Timeline from the initial introduction to the mass market deployment of C-V2X Use cases

The white paper finally highlights the spectrum needs for basic and advanced driving use cases. For direct communication, this corresponds to between 10 and 20 MHz at 5.9 GHz for basic safety, and an additional 40 MHz or more at 5.9 GHz for advanced driving. For mobile network based communications this corresponds to additional availability of spectrum in low-bands (< 1 GHz) and in mid-bands (1-7 GHz) for use by mobile operators in delivering advanced driving capabilities in rural and urban environments, respectively.

To deliver end-to-end V2X services and unlock the true value of vehicle connectivity, 5GAA considers that the realisation of its roadmap would require (1) sufficient spectrum for short-range direct communications at 5.9 GHz, (2) high levels of mobile network coverage along the roads, and (3) sufficient service-agnostic mobile network spectrum for mobile network-based communications, in addition to the bands that are currently identified for International Mobile Telecommunications (IMT)[6] use.

5GAA emphasises that the introduction of the identified use cases also depends on the availability of appropriate regulatory frameworks as described, for example, by ERTRAC[7]. Investment in digital twins for road infrastructure and traffic management, including operational data interfaces, will need to complement the evolution of communication technologies and use cases, but this is outside the scope of this white paper.

5GAA, representing both the automotive and telecommunications industries involved in the deployment of V2X, underlines the need for strong cooperation with policymakers to realise this roadmap. Only an enabling and future-proof regulatory environment, conducive to C-V2X rapid deployment by OEMs and road authorities, will deliver upon our shared goals to improve road safety and reach climate-neutrality for the benefits of society overall.

6 https://www.itu.int/en/ITU-R/Documents/ITU-R-FAQ-IMT.pdf

7 https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf

1. Introduction

The 5G Automotive Association (5GAA) brings together the automotive and telecommunications industries to address society's connected mobility, advanced vulnerable road user (VRU) protection, and road safety needs with applications such as automated driving and the integration of road users into intelligent transportation and traffic management systems. 5GAA considers Cellular Vehicle-To-Everything (C-V2X) technologies[8] – as specified by 3GPP – to be an essential step towards fully integrated intelligent transport systems (ITS) via 5G. Figure 2 illustrates the different communication modes of C-V2X.

This white paper builds on 5GAA's activities which aim to define basic safety and advanced use cases, and to provide a detailed assessment of the relevant standards, technologies, spectrum availability, and timelines for market readiness. It also includes industry recommendations to regulators in order to ensure that the corresponding spectrum is made available in time for the market introduction of these new use cases, leveraging technology evolution, on the road to automotive automation[9]. Even though this white paper discusses advanced driving use cases, one important aspect that should not be overlooked is the need for connectivity to support, for example, remote working and telematics services during travel. This becomes even more important with the advent of autonomous vehicles and efforts to encourage greener transportation through shared use of vehicles.

Work on the various use cases also builds on numerous ongoing efforts by standardisation bodies on the next-generation radio interfaces that will increase the capacity of direct and mobile network-based communications, thus enabling advanced use cases. Automotive and telecommunication companies are very much engaged in these standardisation efforts, and this white paper aims to give an overview of the roadmap for introducing these new cases, together with the necessary regulatory and spectrum policy requirements. In this context, basic safety V2X services defined the requirements for 3GPP Rel-14, and enhancements have continued in Rel-15. 3GPP Rel-16 and beyond will enable advanced driving through sensor sharing, intention sharing and cooperative perception, delivered with unprecedented key performance indicators such as latency and reliability.

[8] Cellular-V2X (C-V2X) is an umbrella term which encapsulates all 3GPP V2X technologies, including both direct (PC5) and mobile network communications (Uu), unless otherwise stated. If only direct or only mobile network communications are addressed, then the terms "direct" and "mobile network" are used, respectively. LTE-V2X relates to all 3GPP releases supporting LTE-V2X mobile network communications and LTE-V2X direct communications. LTE-V2X mobile network communications relate to 3GPP specifications, starting with Rel. 8 for LTE. LTE-V2X direct communications relate to 3GPP specifications, starting with Rel. 14. 5G-V2X relates to the combination of LTE-V2X and 5G radio access technology (NR). 5G-V2X mobile network communications is a combination of LTE-V2X mobile network communications and 5G radio access technology for mobile network communications (NR), which relate to 3GPP specifications, starting with Rel. 15. 5G-V2X direct communications is a combination of LTE-V2X direct communications and 5G radio access technology for direct communications, which relate to 3GPP specifications, starting with Rel. 16.

[9] Innovation and Development Strategy for Intelligent and Connected Vehicle (Final Release Feb. 2020) https://www.its.dot.gov/stratplan2020/ITSJPO_StrategicPlan_2020-2025.pdf

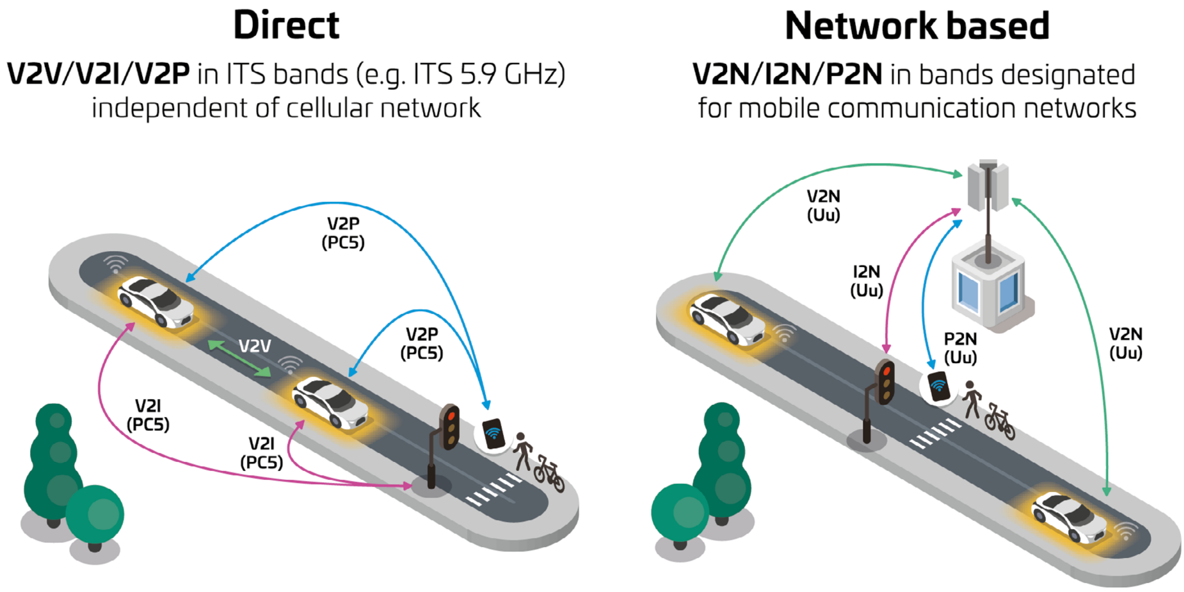


Figure 2: Direct and mobile network based communications modes supported by C-V2X

The different life cycles of vehicles and communication technologies imply that interoperability and backward compatibility are of critical importance. Given that technology evolution is a gradual process, 5GAA advocates a flexible and holistic system approach, combining network-based and direct communication possibilities and their interoperable evolution. This roadmap aims at clarifying these different aspects, from technology to standards to spectrum availability and market introduction.

Lastly, joint industry efforts must be supported by effective policy goals and objectives, promoting greener and more inclusive policies, including in the automotive sector, while accounting for the fact that citizens today require ubiquitous connectivity and innovative automotive-related services. In this context, it is essential to provide the necessary clarity around the market introduction of various new functionalities towards advanced driving.

It is important to recognise that the automotive industry has already gained comprehensive experience on which to build: more than 180 million connected vehicles are on the roads in 2020[10] and a rapidly growing number of vehicles have the capability to exchange traffic and road condition warnings with one another over cellular networks.

[10] 4G, 5G, C-V2X, and 802.11p Connected Vehicles: Global Market Analysis and Forecasts, https://tractica.omdia.com/research/cellular-v2x/

2. 5GAA visionary roadmap for the introduction of advanced use cases for connected and automated driving

5GAA members have studied and established timelines for the introduction of a number of promising advanced use cases accounting for major global developments, including those in China, Europe and the US. These regions are today the largest automotive markets and generate a great deal of momentum around connected vehicles and advanced driving. Noteworthy developments are also observed in countries such as South Korea, Australia and Japan, and 5GAA is thus actively engaging with these countries as well. These use cases, together with their service level requirements (SLRs) are detailed in the complementary 5GAA C-V2X Use Cases White Paper[11]. As indicated in Figure 3 below, the use case timelines can be segmented into four phases which reflect increasing complexity and technical requirements.

In 2020, we expect that use cases such as Traffic Information and Local Hazard will be complemented with C-V2X direct communication and will lay the foundations for road safety and traffic efficiency. From 2022 onwards, advanced use cases such as Hazard Information Sharing for Automated Vehicles (AVs) and HD Map Sharing for AVs will gradually contribute to the building blocks required for automated driving.

Initial versions of certain advanced V2N use cases, such as Tele-Operated Driving and Automated Valet Parking, can already be implemented today by individual OEMs with LTE-V2X network-based communications and on-board sensors in controlled environments, such as on private campuses. By 2025/26, we expect that these use cases will be extended to operate in more complex environments and scenarios, such as on public roads and in parking garages, leveraging 5G-V2X.

Cooperative Manoeuvres (via direct communication) and Sensor Sharing to support cooperative perception – both basic functionalities for automated driving, e.g. Highway Pilot – are supported by 5G-V2X. We predict that all new AD vehicles will be equipped with 5G-V2X from 2026, in line with their mass production and entry to the market. Complex interactions between vehicles and VRUs via mobile phones – through both direct (PC5) and network-based (Uu) C-V2X communications – are foreseen to start by 2027.

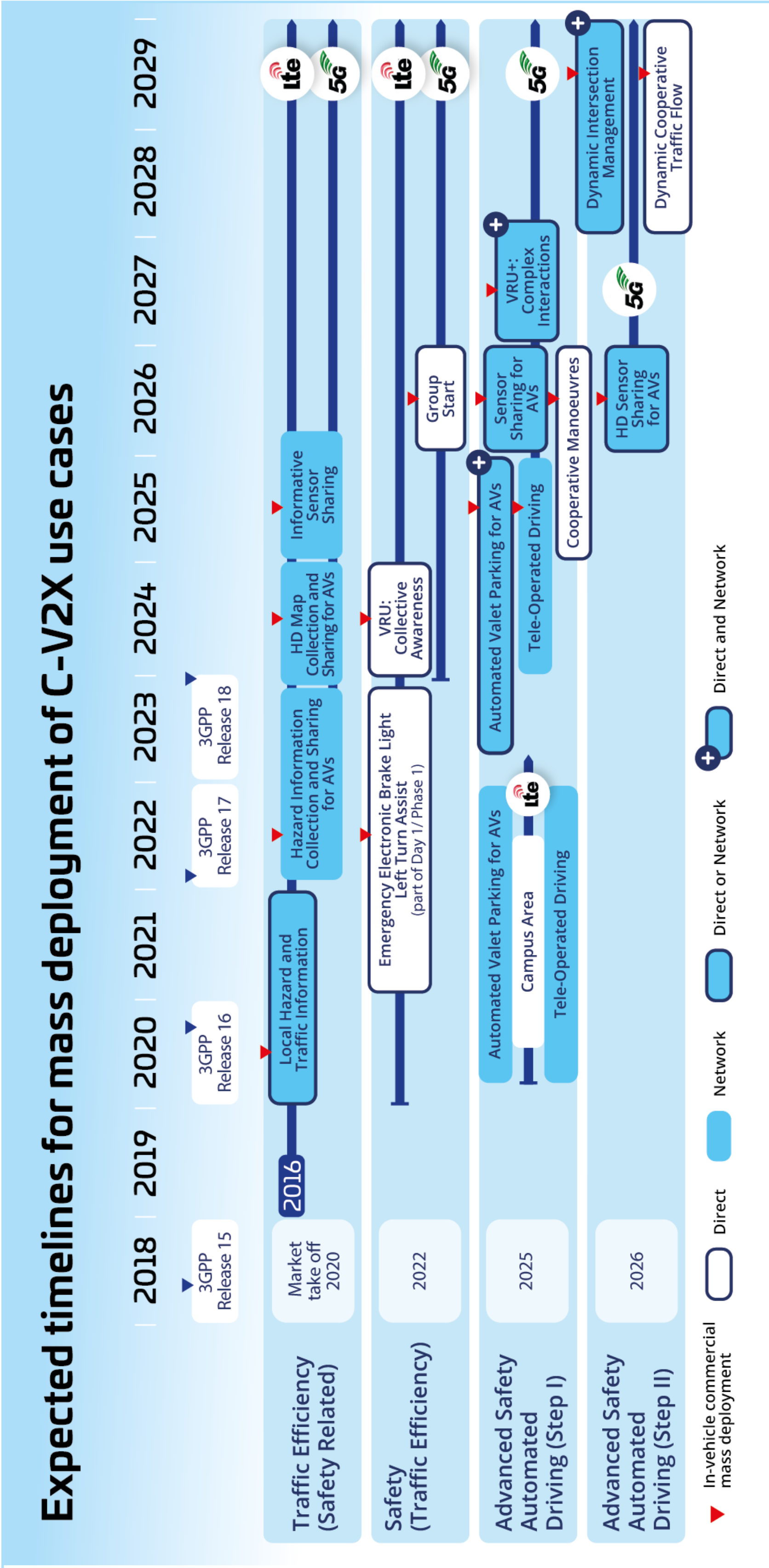
[11] 5GAA white paper: C-V2X use cases volume II: Examples and service level requirements with the use case correspondence listed in the annex https://5gaa.org/news/5gaa-releases-white-paper-on-c-v2x-use-cases-methodology-examples-and-service-level-requirements/

It is to be noted that, in the foreseeable future, we will have a combination of connected and automated vehicles co-existing with normal vehicles that are not enabled by automated driving functions. Connectivity will support automation levels, but also bring benefits to mixed traffic situations, already enabling some use cases on the road to automation.

High-Definition Sensor Sharing, based on 5G-V2X will support the development of further automated driving levels in the future, with first pilots expected after 2026. Enhanced urban and highway pilots are expected to start in 2029 in dedicated areas allowing Dynamic Cooperative Traffic Flow and Dynamic Intersection Management.

According to our studies, additional spectrum for direct communications (including the entire 5850-5925 MHz band globally harmonised for ITS) and for mobile network-based communications (particularly below 1 GHz low-band frequencies and 1-7 GHz mid-band frequencies) will have to be made available for the implementation of many of the use cases identified in the roadmap. This is particularly the case for HD Map Sharing (Uu), Tele-Operated Driving (Uu), Cooperative Manoeuvres (PC5), Sensor Sharing (Uu/PC5), Dynamic Intersection Management (Uu+PC5), Dynamic Cooperative Traffic Flow (PC5), and Complex Interactions with VRUs (Uu+PC5).

Figure 3: Expected timelines for mass deployment of C-V2X use cases



3. Standards

C-V2X builds on cellular mobile network communications (Uu interface) as well as direct communications (PC5/sidelink interface) as defined by 3GPP. The specifications for LTE-V2X Rel-14/15 are finalised. The work on Rel-16 – incorporating specifications for 5G-V2X – and subsequent releases is ongoing in 3GPP.

Generally speaking, the communication layers specified in 3GPP describe the radio communication capabilities and functionalities of C-V2X. Industry continues to develop the upper layers for the support of various use cases by standardisation bodies such as ETSI, SAE, C-SAE, and ISO. These profiles and protocols are then being implemented in end-to-end systems to enable ITS use cases. However, work on the upper layers is often region-specific, taking into account applicable considerations and regulations.

4. 5GAA radio spectrum roadmap

Based on the results of our studies[12], it is the view of the 5GAA that the provision of envisaged advanced driving use cases by LTE-V2X and 5G-V2X for direct communications will require availability of the entire 5.9 GHz band (5850-5925 MHz) which is globally harmonised for ITS by the ITU-R[13]. As the ITS industry develops further, and we begin to better understand the demands of advanced safety and automated driving, we will assess the extent to which the 5.9 GHz is sufficient to meet road users' spectrum needs, and whether additional spectrum designated for ITS will be required.

In light of this, it is the view of 5GAA that national administrations should make as much as possible of the 5.9 GHz band available for use by ITS. Specifically, our positions in relation to China, Europe, and the US are as follows:

China

In China, 5905-5925 MHz (20 MHz) is currently allocated for use by LTE-V2X direct communications for the delivery of ITS services, with the lower 10 MHz block for Vehicle to Vehicle (V2V) communications, and the upper 10 MHz block for Vehicle to Infrastructure (V2I) communications. We expect that this allocation will be sufficient to support initial use cases, but that advanced use cases will require additional spectrum. 5GAA thereby recommends that spectrum availability for C-V2X direct communications in China be extended in accordance with the globally harmonised 5850-5925 MHz band for ITS applications as defined by the ITU-R.

12 5GAA 'Study of spectrum needs for safety related intelligent transportation systems – day-1 and advanced use cases', https://5gaa.org/news/study-of-spectrum-needs-for-safety-related intelligent-transportation-systems-day-1-and-advanced-use-cases/

13 ITU Recommendation 2121, https://www.itu.int/rec/R-REC-M.2121-0-201901-I/en

Europe

The availability of spectrum for ITS in Europe is broadly aligned with the globally harmonised 5850-5925 MHz band as defined by the ITU-R. In Europe, 5855-5875 MHz is designated for non-safety road ITS, whereas 5875-5935 MHz is designated for safety-related ITS. This availability is on a technology neutral basis.

United States

The US is currently consulting on the allocation of 5905-5925 MHz (20 MHz) to C-V2X direct communications, along with the option of allocating 5895-5905 MHz to C-V2X direct communications or DSRC. As outlined above, and in light of the demand for spectrum by advanced use cases, 5GAA recommends that the spectrum availability for C-V2X direct communications in the US be extended in accordance with the globally harmonised 5850-5925 MHz band for ITS applications as defined by the ITU-R.

Furthermore, our studies indicate that the current spectrum allocations available to mobile operators are not sufficient to support the advanced mobile network-based communications anticipated by the automotive industry. It is the view of the 5GAA that national and regional administrations address this with the following complementary actions:

- At least 50 MHz of additional service-agnostic low-band (< 1 GHz) spectrum be made available for mobile network operators to provide advanced automotive V2N services in rural environments with affordable deployment costs.

- At least 500 MHz of additional service-agnostic mid-band (1 to 7 GHz) spectrum be made available for mobile network operators to provide high capacity city-wide advanced automotive V2N services.

In the above, the term "additional" means availability of spectrum in addition to the bands that are currently identified for IMT use by mobile communication networks.

5. Conclusions and recommendations

Based on our vision, we believe that success in the field of advanced safety, automated driving and connected mobility will involve the engagement of all stakeholders, including the telecommunications and automotive industries, in order to foster new business models and investment paradigms. The integration of road and telecommunication infrastructures will deliver better coverage of vulnerable road users, along with enhanced capabilities in vehicles as sensors are further enabled through connectivity. We recognise that there are certain challenges, for example in future protocols, implementation descriptions and conformity/testing needed for advanced driving use cases, which ought to be addressed by 5GAA together with the relevant standards developing organisations (SDOs) and wider industry ecosystem.

We currently face a convergence of multiple trends in the automotive industry that have the potential to dramatically change mobility. Connected vehicles and road/telecommunication infrastructures form a new single digital ecosystem where wireless networks will play a major role in interconnecting elements of the distributed system. The 5GAA roadmap will serve to guide the parties involved in the ecosystem by identifying the required use cases and services which are expected to be enabled by 5G-V2X in the coming decade. This white paper highlights selected end-to-end solutions, and considers their spectrum needs as well as the required technology evolution and readiness.

The Traffic Efficiency track in the roadmap (see Figure 3) lists the entry use cases to be discussed with road operators in order to enable a true Digital Roads vision. As an initial step, digital infrastructure will bring dynamic traffic information, hazard warnings, and HD maps to the driver (up to 2024). In a second step, cooperate manoeuvres and HD sensor sharing provided by road operators will support automated driving above Level 2 through “cooperative perception” (2026). Finally dynamic cooperative driving enabled with the support of road operators at selected hotspots (e.g. intersections) will follow (2029).

The Safety Track of the roadmap is a guide for upcoming NCAP discussions in Europe, Asia and the US, with the aim of reducing collisions, injuries and fatalities associated with vehicles employing C-V2X by 2022. The challenge of zero fatalities for VRUs is addressed in two steps. First by leveraging sensors to detect the VRUs, and roadside units to alert the driver (Collective Awareness, 2024). Second by fully integrating VRUs’ mobile handsets into the ecosystem to enable complex interactions between vehicles and pedestrians, (e-)bikes, and scooters (Complex Interactions, 2027).

The cellular approach offers a unique combination of direct and network-based communications to cover the requirements and needs of all concerned stakeholders for Advanced Safety and Automated Driving. For mobile network operators, all the tracks in the roadmap present examples of future uses of the upcoming 5G-V2X networks. Building on the unique 5G-V2X features, traffic management as well as automated driving requirements can be fulfilled. Low hanging fruit applications addressing OEM fleets, such as Automated Valet Parking and Tele-Operated Driving will open the door to more secure, safe, and interoperable network-based automotive applications across borders.

The 5GAA roadmap provides a joint stakeholder view for the automotive world. As automated vehicles need a specifically adapted end-to-end architecture, an entire new value chain of chip-makers, device manufactures, mobile network operators and OEMs has to be established. Tracks 3 and 4 of the roadmap link for the first time the readiness of C-V2X technology to automated driving levels. The initial step of connected automated driving starts in campus areas in Track 3, while the final step in Track 4 provides a glimpse, confirmed by OEMs, of the future of connected automated driving. The 5GAA roadmap can be used as a guide to establish the required partnerships among all stakeholders.

On the matter of spectrum, the 5GAA strongly recommends that national administrations make the entire globally harmonised 5855-5925 MHz band available for use by ITS communications between road users and between road users and roadside ITS infrastructure, as supported by the PC5 interface of C-V2X. The 5GAA also places a high value on the importance of communications between road users and mobile network infrastructures in enabling future advanced driving use cases, as supported by the Uu interface of C-V2X. Accordingly, the 5GAA recommends that national and regional administrations ensure the availability of sufficient spectrum for mobile communication networks in the so-called low-bands and mid-bands for the support of services, including ITS, in the coming decade.

From a business perspective, our roadmap is a call for all players to engage and collaborate in order to enable the rapid take-up of these use cases and to deliver societal benefits.

And finally, from a policy perspective, we look forward to working with regulators and policymakers to design a future-proof regulatory framework, conducive to new partnerships and providing clarity on the obligations of various parties.

5GAA
Automotive Association

APPENDIX B

5GAA
Automotive Association

C-V2X Use Cases and Service Level Requirements Volume I

5GAA Automotive Association
Technical Report

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Contents

Foreword

This Technical Report has been produced by 5GAA.

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

x-nnzzzz

(1) This numbering system has six logical elements:

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

where x =

T (Use Cases and Technical Requirements)

A (System Architecture and Solution Development)

P (Evaluation, Testbed and Pilots)

S (Standards and Spectrum)

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

(b) nn: two digits to indicate the year. i.e. 16,17,18, etc.

(c) zzzz: unique number of the document

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

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

1 Scope

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

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

2 References

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

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

[1] 5GAA T-170024, "5GAA Board Internal Guidance Document: Vision and Principles," Barcelona, February 2017

[2] 5GAA T-170044, "Work Item Description: Use Case and KPI requirements," Barcelona, Spain, February 2017

[3] 5GAA T-180065, "Work Item Description: Use Case and Service Level Requirements", Munich, Germany, February 2018

[4] 5GAA T-170060, Use Cases: Automotive view of requirements

[5] 5GAA T-170077, Definitions for C-V2X Use Case framework

[6] 5GAA T-170090, Use Case Descriptions

[7] 5GAA T-170100, Use Case Framework, May 2017.

[8] 5GAA T-170105, Daimler, Ford, "Proposal for a Common Template for Defining Use Cases in WG1," June 2017

[9] 5GAA T-170108, Denso, Huawei, Nokia, Intel, "On Road Environment, Use Cases and scenarios: a hierarchical approach," June 2017

[10] 5GAA T-170109, Denso, Huawei, Nokia, Intel, "New template for Use Cases definitions," June 2017

[11] ETSI TR 102 638, Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions, June 2009

[12] 5GAA T-180029, "Use Case and KPI requirements: Prioritization and Timeline; Interims Status – V1.3", January 2018

[13] 5GAA T-180101, "Extended template for Use Cases definitions", Intel, Denso, Ford, May 10, 2018

[14] 5GAA T-180004, "Service Level Requirements (SLRs) Table", 2018

[15] 5GAA T-180233, "Use Case description: Cross-Traffic Left-Turn Assist", November 2018

[16] 5GAA T-180229, "Use Case description: Intersection Movement Assist", November 2018

[17] 5GAA T-180234, "Use Case description: Emergency Brake Warning", November 2018

[18] 5GAA T-180241, "Use Case description: Traffic Jam Warning and Route Information", November 2018

[19] 5GAA T-180153, "Use Case description: Software Update", July 2018

[20] 5GAA T-180214, "Use Case description: Vehicle Health Monitoring", November 2018

[21] 5GAA T-180170, "Use Case description: Real-Time Situational Awareness & High Definition Map: Hazardous Location Warning", July 2018

[22] 5GAA T-180255, "Use Case description: Speed Harmonisation", December 2018

[23] 5GAA T-180216, "Use Case description: High Definition Sensor Sharing", November 2018

[24] 5GAA T-180235, "Use Case description: See Through for Passing ", October 2018

[25] 5GAA T-180256, "Use Case description: Cooperative Lane Change (CLC) of Automated Vehicles: Lane Change Warning", November 2018

[26] 5GAA T-190161, "Use Case description: Vulnerable Road User (VRU)", September 2019

[27] 5GAA TR T-190007, "Use Case and KPI requirements: Prioritization and Timeline V2.0", January 2019

3 Definitions and Abbreviations

3.1 Definitions

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

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

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

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

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

3.2 Abbreviations

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

SLR Service Level Requirement

4 Introduction

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

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

- T-170060: Use Cases: Automotive view of requirements [4]
- T-170077: Definitions for C-V2X Use Case framework [5]
- T-170090: Use Case Descriptions [6]
- T-170105: Proposal for a common template for defining Use Cases [8]

- T-170108: On Road Environment, Use Cases and scenarios: a hierarchical approach [9]
- T-170109: New template for Use Case definitions [10]
- T-180101: Extended template for Use Cases definitions [13]

Previous versions of the present report were published as 5GAA T-180029 [12] and 5GAA TR T-190007 [27].

The original Use Case descriptions were developed in separate documents as listed below. The present document presents consolidated SLRs refining the previously derived SLRs. Note that this means that some of the values in the original descriptions referred to below are outdated.

- 5GAA T-180233: Cross-Traffic Left-Turn Assist [15]
- 5GAA T-180229: Intersection Movement Assist [16]
- 5GAA T-180234: Emergency Brake Warning [17]
- 5GAA T-180241: Traffic Jam Warning [18]
- 5GAA T-180153: Software Update [19]
- 5GAA T-180214: Remote Vehicle Health Monitoring [20]
- 5GAA T-180170: Real-Time Situational Awareness & High Definition Maps: Hazardous Location Warning [21]
- 5GAA T-180255: Speed Harmonisation [22]
- 5GAA T-180216: High Definition Sensor Sharing [23]
- 5GAA T-180235: See-Through [24]
- 5GAA T-180256: Cooperative Lane Change (CLC) of Automated Vehicles: Lane Change Warning [25]
- 5GAA T-180171: Vulnerable Road User [26]

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

5 C-V2X Use Cases Description Framework

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

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

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

1. **Road Environments**: Road Environments are the typical places where vehicle traffic and C-V2X Use Cases occur, such as intersections, urban and rural streets, high-speed roads (autobahn), parking lots, etc. Each Use Case should be mapped to at least one Road Environment, while the latter can be associated with one or more Use Cases. In combination, multiple Use Cases form the communication performance requirements in an environment.
   It should be noted that the preparation of an exhaustive list of Road Environments is not in the scope of the current WI in WG1.
2. **Use Cases**: Use Cases are the high-level procedures for executing an application in a particular situation with a specific purpose [1]. A Use Case may entail a number of specific User Stories, where different requirements may apply. 5GAA WG1 is currently studying 12 Use Cases initially recommended by the 5GAA board, from which six have being prioritised for the development of the framework for requirement analysis.
   Note that one main goal of this hierarchical classification scheme is to describe Use Cases as “atomic” units in order to reduce complexity. The rationale behind this approach is to define simple Use Cases rather than one combined complex Use Case.

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

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

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

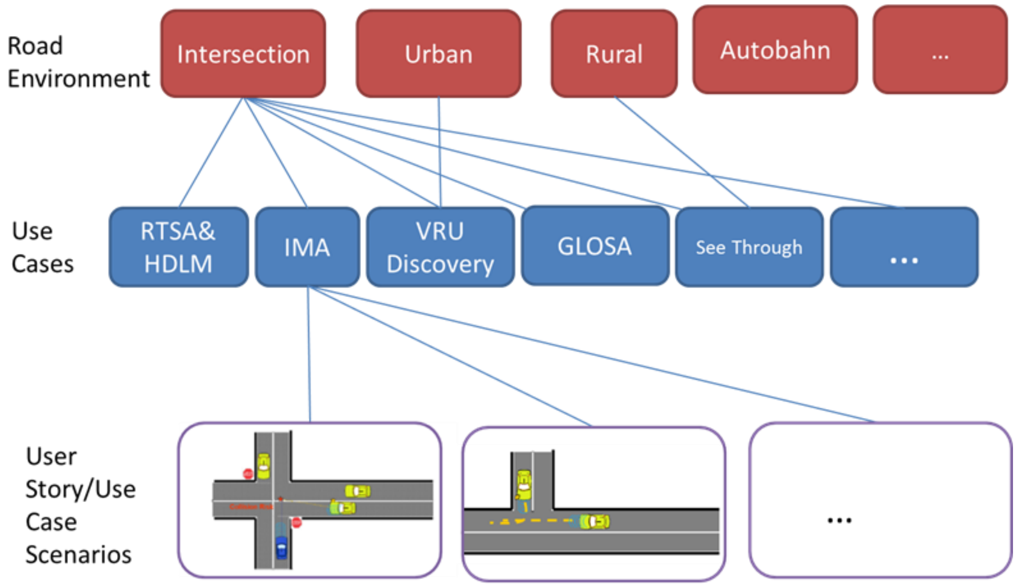


Figure 1 Hierarchies

We can observe that:

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

5.2 Template for Use Case Descriptions

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

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

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

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

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

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

Table 1: Template for Use Case Descriptions

User Story	**Detailed description and specifics**
User Story #1	
User Story #2	
.....	

Table 2: Template User Stories

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

Information requested/generated	**Quality of information/ Information needs**		
Service Level Latency	**[ms]**		
Service Level Reliability			
Velocity	**[m/s]**		
Vehicle Density	**[vehicle/km^2]**		
Positioning Accuracy	**[m]**		
Interoperability / Regulatory / Standardisation Required	**[yes/no]**		

Table 3: Template Service Level Requirements

5.3 Use Case Classification Scheme

This section introduces the categorisation/grouping view for the Use Cases, as introduced in **Error! Reference source not found.**. As mentioned in **Error! Reference source not found.**, one goal is to more easily identify which stakeholder would benefit and have an incentive to drive the realisation of the Use Case (UC) and, optionally, participate in the financing of the UC. Additionally, the grouping of the UCs is supposed to simplify communication with other working groups, and aid their tasks, e.g. what to prioritise.

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

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

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

The following new groups were agreed in 5GAA WG1:

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

5.3.1 Safety

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

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

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

5.3.2 Vehicle Operations Management

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

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

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

5.3.3 Convenience

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

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

5.3.4 Autonomous Driving

This Use Case group address Use Cases that are relevant for Autonomous/self driving vehicles (level 4 and 5), examples in this group are Control if autonomous driving is allowed or not, Tele-operation (potentially with Augmented Reality support), handling of dynamic maps (update/download), some of the Safety UCs that require cooperative interaction between vehicles to be efficient and safe.

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

5.3.5 Platooning

This Use Case group address Use Cases that are relevant for platooning, examples in this group are platoon management, e.g. collect and establish a platoon, determine position in platoon, dissolve a platoon, manage distance within platoon, leave a platoon, control of platoon in steady state, request passing through a platoon.

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

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

5.3.6 Traffic Efficiency and Environmental Friendliness

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

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

5.3.7 Society and Community

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

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

5.4 C-V2X Use Case Requirements

5.4.1 Introduction

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

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

5.4.2 Service Level Requirements Definitions

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

- Range
  - Definition: Expected distance from HV to scenario application zone
  - Comments: N/a
  - Test: The Use Case test should include the distance equal to the range between the HV and the scenario application zone.
- Information requested/generated
  - Definition: Quality of information/information needs of the end-user (e.g. a driver, a passenger, robot in the car or remote driver, application programme running in an ECU, etc.). In this description, the end result of the information delivery is important while the actual transfer is not a concern.
  - Comments: Examples:
    - Infotainment: Passengers are viewing a video stream with a certain resolution and a certain frame update rate.
    - Software update: Vehicle needs to receive a software package of a given size within perhaps a deadline.
    - Safety: Vehicle needs information on the precise location of other vehicles currently in its vicinity and in the near future.
    - Quality of Information (QoI) in different contexts has the following attributes:
      - Timeliness
      - Appropriateness
      - Reliability
      - Accuracy

            - Completeness
            - Conciseness
            - Security
    - Test: The Use Case test should include, for example:
        - Size of the software update
        - Video signal quality
        - Enough information to determine the future dynamics of the vehicle
- Service Level Latency
    - Definition: Measurements of time from the occurrence of the event in a scenario application zone to the beginning of the resulting actuation. Depending on implementation, this includes one or more of the following:
        - Processing of the event into information by the information generator
        - Communication of the information to end-user
        - Processing of the information by the end-user
        - Time to actuation driven by the information processing results
    - Comments: It can be assumed that measurement of time starts when the information is generated. This requirement can be context-driven, e.g. for ‘see-through’ we can request that video be available no more than “T” after the need is expressed.
    - Test: The Use Case test should measure the time interval from the instant the information is requested/generated until the information is available at the destination.
- Service Level Reliability
    - Definition: Based on an agreed QoS framework, the guaranteed and expected performance to start/initialise, perform and finalise (end-to-end) applications within Use Cases. Different agreed and provided QoS levels will result in different performances within the applications. Known or expected changes in Service Level Reliability before starting an application or during operation should be announced in a timely fashion (close to the relevant applications and entities involved).
    - Comments: N/a
    - Test: Tbd
- Velocity
    - Definition: Describes the maximum absolute speed of a vehicle at which a defined QoS can be achieved (in km/h). It describes the extent of the mobility and the average speed of the vehicle involved in the Use Case. Note that there may be a need to capture the peak expected speed. This definition may also be required to be split in order to describe the type of mobility from the speed. For instance, ‘nomadic’ is a type of mobility.
    - Comments: N/a
    - Test: The Use Case should be tested with vehicle speeds specified in this requirement.
- Vehicle Density
    - Definition: Expected number of vehicles per given area (per km2) during the execution of the Use Case. Note that indicates that multiple vehicles within the same area run the same (and potentially additional) Use Case(s) in parallel.
    - Comments: N/a
    - Test: The Use Case should be tested with the vehicle density specified in this requirement. Note that this does not necessarily mean large number of vehicles; however, the impact of the vehicle density needs to be tested.
- Positioning
    - Definition: Positioning/position/location accuracy at the time when position information is delivered to the end-user (HV), between the actual position and the position information.
        - Location type: Absolute/geographical or relative or N/A
        - KPI: Accuracy level
    - Comments: How to measure accuracy and how to measure the error? Options are:
        - When the information is generated at the source
        - Or when the information is delivered to the HV (end-user)
    - Test: The Use Case is tested with at least the accuracy of positioning according to this requirement.
- Interoperability/Regulatory/Standardisation Required
    - Definition: Yes/No, to indicate the need for inter-OEM interoperability, e.g. in cooperative safety Use Cases
    - Comments: N/a
    - Test: The Use Case shall be tested between different OEMs and/or different device manufacturers

5.4.3 Automotive View of C-V2X Use Case Requirements

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

6 C-V2X Use Case Descriptions

This section contains description of the Use Cases developed by 5GAA WG1. According to the Use Case grouping introduced in [7], the Use Cases are classified into four groups: Safety, Convenience, Advanced Driving Assistance, and VRU. As shown in Figure 1, each Use Case can be composed of multiple User Stories, wherein User Stories can differ in terms of road configuration, actors involved, service flows, etc.

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

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

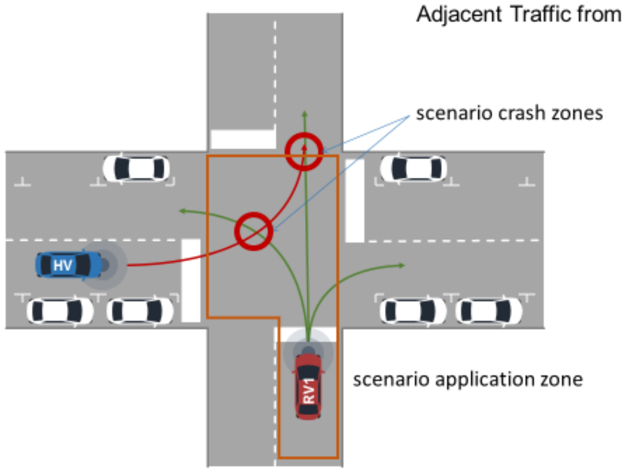
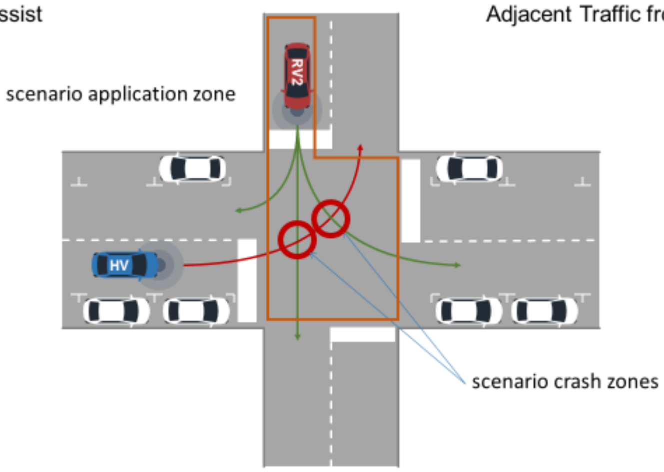
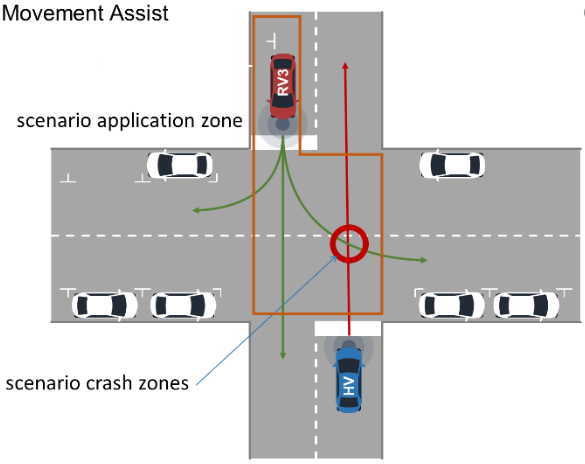
Note that it is also assumed that messages are exchanged in a secure way between authenticated parties.

6.1 Safety

6.1.1 Cross-Traffic Left-Turn Assist

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

Roadside Infrastructure Roles	• Roads are defined by their lane designations and geometry. • Intersections are defined by their crossing designations and geometry. • Traffic lights and stop signs control right of way traffic flow through an intersection (if available). • Local traffic laws and rules control right of way through three-way stops, four-way stops and unsigned intersections.
Other Actors' Roles	Not applicable.
Goal	• Avoid a lateral collision between HV and RV1. • Avoid a lateral collision between HV and RV2. • Avoid an oncoming collision between HV and RV3.
Needs	• HV needs to know if there is a risk of collision with RV1 approaching from the right. • HV needs to know if there is a risk of collision with RV2 approaching from the left. • HV needs to know if there is a risk of collision with an oncoming RV3.
Constraints/ Presumptions	• RV1's intended direction through the intersection is known or can be guessed based on past values. • RV2's intended direction through the intersection is known or can be guessed based on past values. • RV3's intended direction through the intersection is known or can be guessed based on past values.
Geographic Scope	Global.

Illustrations	Left Turn Assist Adjacent Traffic from the Right  Left Turn Assist Adjacent Traffic from the Left  Intersection Movement Assist Oncoming Traffic 

<table>
<tr><td>Pre-Conditions</td><td>

HV is stopped at or moving towards an intersection.
HV signals its intention to turn left.
The “Adjacent Traffic from the Right” scenario application zone is determined from:
HV’s location
lane designations and geometry
intersection geometry
posted speed limits
Road conditions (if available)
The “Adjacent Traffic from the Left” scenario application zone is determined from:
HV’s location
lane designations and geometry
intersection geometry
posted speed limits
Road conditions (if available)
The “Oncoming Traffic” scenario application zone is determined from:
HV’s location
lane designations and geometry
intersection geometry
posted speed limits
Road conditions (if available)
</td></tr>
<tr><td>Main Event Flow</td><td>

RV1 is in the “Adjacent Traffic from the Right” scenario application zone.
If RV1 has the right of way:

RV1’s trajectory through the intersection is estimated using:
RV1’s location and dynamics
RV1’s turn signal state
Lane designations and geometry
Intersection geometry
HV’s trajectory through the intersection is estimated using;
HV’s location
HV’s estimated acceleration
Lane designations and geometry
Intersection geometry
If there is a risk of collision based on the estimated trajectories of HV and RV1 then:
HV is warned of a risk of collision with RV1 approaching from the right

Otherwise if HV has the right of way:

RV1’s stopping distance is estimated using:
RV1’s location and dynamics
Lane designations and geometry
Intersection geometry
Road conditions (if available)
If there is a risk that RV1 cannot stop before the intersection:
HV is warned of a risk of collision with RV1 approaching from the right

</td></tr>
</table>

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

Post-Conditions	• RV3 is in the "Oncoming Traffic" scenario application zone.
	• If RV3 has the right of way:
	  ○ RV3's trajectory through the intersection is estimated using:
	    ▪ RV3's location and dynamics
	    ▪ RV3's turn signal state
	    ▪ Lane designations and geometry
	    ▪ Intersection geometry
	  ○ HV's trajectory through the intersection is estimated using:
	    ▪ HV's location
	    ▪ HV's estimated acceleration
	    ▪ Lane designations and geometry
	    ▪ Intersection geometry
	  ○ If there is a risk of collision based on the estimated trajectories of HV and RV3 then:
	    ▪ HV is warned of a risk of collision with oncoming RV3
	• Otherwise if HV has the right of way:
	  ○ RV3's trajectory and stopping distance is estimated using;
	    ▪ RV3's location and dynamics
	    ▪ RV3's turn signal state
	    ▪ Lane designations and geometry
	    ▪ Intersection geometry
	    ▪ Road conditions (if available)
	  ○ If there is a risk that RV3 cannot stop before the intersection:
	    ▪ HV is warned of a risk of collision with oncoming RV3

Service Level Requirements	• Positioning accuracy. • Information age. • Communications range.

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

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

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

Table to specify the corresponding Service Level Requirements:

User Story #1 (all scenarios, no matter which direction traffic is coming from)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	300	Maximum communication range assumed, this allows for ~5 s to react (at the max. speed mentioned within the velocity section).
Information Requested/Generated	**Quality of information/ Information needs**	300 B per message	LTA in User Story one is based on normal CAM exchange.
Service Level Latency	**[ms]**	100	Normal CAM message latency.
Service Level Reliability		90 %	For single CAM messages without retransmission, this reliability is enough to ensure the ETSI requirement of <5 % probability

			of two consecutive CAM message transmission failing.
Velocity	**[m/s]**	28	Most critical situations are to be expected at rural intersections. Here, the RV could be driving at up to 100 km/h, and the HV that wants to turn is slowing down, possibly also from 100 km/h. Therefore, maximum speeds of 100 km/h seem to be a reasonable value.
Vehicle Density	**[vehicle/km^2]**	1500	This Use Case is expected to mostly happen in less densely populated areas, since visibility at intersections is mostly good, speeds are limited around 50 km/h, and traffic lights can be expected at most intersections. The most probable scenario for the Use Case is envisioned in rural intersections that are hard to see and where higher speeds of the participating cars are expected.
Positioning Accuracy	**[m]**	1.5 (3 σ)	In order to perform lane-accurate positioning, a provisions of around 1 m should be made.
Interoperability / Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Interoperability between different OEMs is needed to the extent that every OEM should be able to receive signals broadcast by another OEM. Further interoperability is not needed. Every vehicle should make its presence known periodically (as a broadcast). Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood.

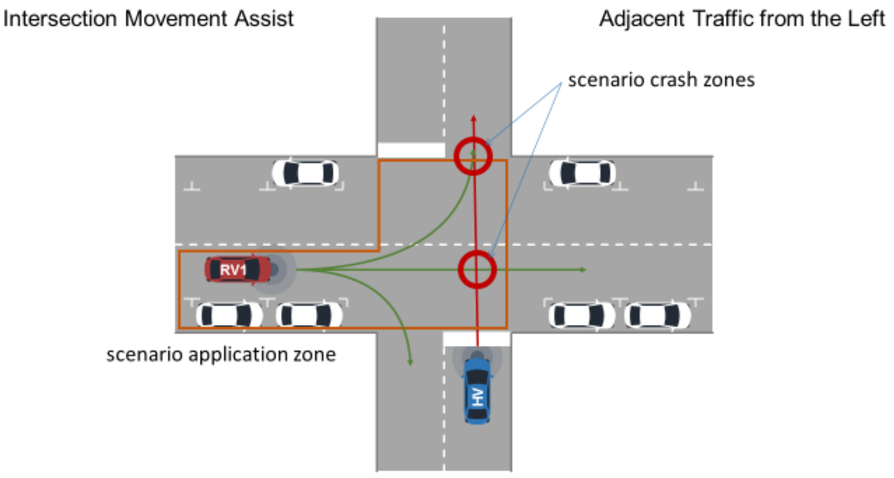
User Story #2 (all scenarios, no matter which direction traffic is coming from)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	300	Maximum communication range assumed, this allows for ~5 s to react (at the max. speed mentioned within the velocity section).
Information Requested/Generated	**Quality of information/ Information needs**	Approx. 1000 B per message	Intended trajectories have to be sent by the RVs, since they determine whether or not a collision is imminent or not. In order to do so, some more payload than with normal CAMs should be used.
Service Level Latency	**[ms]**	10	LTA is a rather critical Use Case. Depending on the implementation, warning messages might be

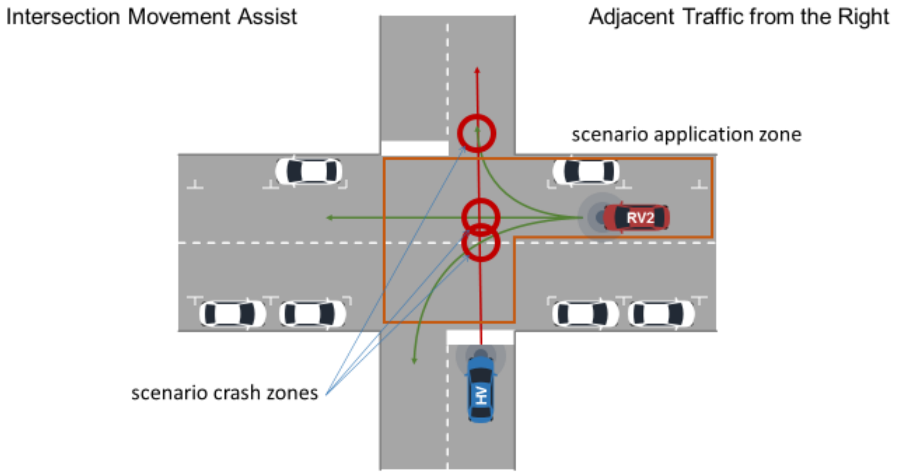
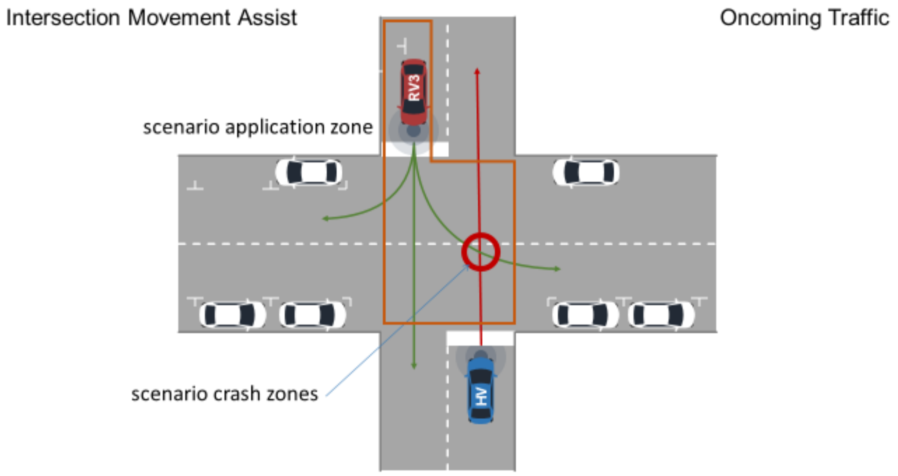
			issued only shortly before actual turning is taking place. Therefore, this sort of a latency seems reasonable.
Service Level Reliability		99.9 %	A SLR this high should be enough to allow perceived zero-error appearance of the cross-traffic left-turn assist. False positives are more problematic than false negatives.
Velocity	**[m/s]**	28	Most critical situations are to be expected at rural intersections. Here, the RV could be driving with up to 100 km/h, and the HV that wants to turn is slowing down, possibly also from 100 km/h. Therefore, maximum speeds of 100 km/h seem to be a reasonable value.
Vehicle Density	**[vehicle/km^2]**	1500	This Use Case is expected to mostly happen in less densely populated areas, since visibility at intersections is mostly good, speeds are limited around 50 km/h, and traffic lights can be expected at most intersections. The most probable scenario for the Use Case is envisioned in rural intersections that are hard to see and where higher speeds of the participating cars are expected.
Positioning Accuracy	**[m]**	1.5 (3 σ)	In order to perform lane-accurate positioning, a positioning accuracy of around 1 m should be provided.
Interoperability Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Interoperability between different OEMs is needed. Every vehicle should make its presence known periodically (as a broadcast). Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood.

6.1.2 Intersection Movement Assist

Use Case Name	Intersection Movement Assist.
User Story	Stationary HV proceeds straight from stop at an intersection. HV is alerted if it is unsafe to proceed through the intersection.
Category	Safety.
Road Environment	Intersections.

Short Description	• Alerts HV that is stopped and intending to proceed straight through the intersection of:
	  ○ Approaching cross-traffic from the left
	  ○ Approaching cross-traffic from the right
	  ○ Oncoming traffic intending to turn left

Actors	• Host vehicle (HV). • Remote vehicle 1 (RV1). • Remote vehicle 2 (RV2). • Remote vehicle 3 (RV3).
Vehicle Roles	• HV represents the vehicle stopped at intersection. • RV1 represents cross-traffic vehicle approaching from the left. • RV2 represents cross-traffic vehicle approaching from the right. • RV3 represents oncoming-traffic vehicle.
Road & Roadside Infrastructure Roles	• Roads are defined by their lane designations and geometry. • Intersections are defined by their crossing designations and geometry. • Traffic lights and stop signs control right of way traffic flow through an intersection (if available). • Local Traffic laws and rules control right of way through three-way stops, four-way stops and unsigned intersections.
Other Actors' Roles	Not applicable.
Goal	• Avoid a lateral collision between HV and RV1. • Avoid a lateral collision between HV and RV2. • Avoid an oncoming collision between HV and RV3.
Needs	• HV needs to know if there is a risk of collision with RV1 approaching from the left. • HV needs to know if there is a risk of collision with RV2 approaching from the right. • HV needs to know if there is a risk of collision with an oncoming RV3.
Constraints/ Presumptions	• The acceleration of HV from stopped must be assumed. • RV1's intended direction through the intersection is known. • RV2's intended direction through the intersection is known. • RV3's intended direction through the intersection is known.
Geographic Scope	• Global
Illustrations	

Pre-Conditions	• HV is stopped at an intersection.
	• The "Adjacent Traffic from the Left" scenario application zone is determined from:
	    o HV's location
	    o lane designations and geometry
	    o intersection geometry
	    o posted speed limits
	    o Road conditions (if available)
	• The "Adjacent Traffic from the Right" scenario application zone is determined from:
	    o HV's location
	    o lane designations and geometry
	    o intersection geometry
	    o posted speed limits
	    o Road conditions (if available)
	• The "Oncoming Traffic" scenario application zone is determined from:
	    o HV's location
	    o lane designations and geometry
	    o intersection geometry
	    o posted speed limits
	    o Road conditions (if available)

Main Event Flow	• RV1 is in the "Adjacent Traffic from the Left" scenario application zone.
	• If RV1 has the right of way:
	    o RV1's trajectory through the intersection is estimated using:
	        ▪ RV1's location and dynamics
	        ▪ RV1's turn signal state

	▪ Lane designations and geometry ▪ Intersection geometry o HV's trajectory through the intersection is estimated using: ▪ HV's location ▪ HV's estimated acceleration ▪ Lane designations and geometry ▪ Intersection geometry o If there is a risk of collision based on the estimated trajectories of HV and RV1 then: ▪ HV is warned of a risk of collision with RV1 approaching from the left • Otherwise if HV has the right of way: o RV1's stopping distance is estimated using: ▪ RV1's location and dynamics ▪ Lane designations and geometry ▪ Intersection geometry ▪ Road conditions (if available) o If there is a risk that RV1 cannot stop before the intersection: ▪ HV is warned of a risk of collision with RV1 approaching from the left
Alternative Event Flow	• RV2 is in the "Adjacent Traffic from the Right" scenario application zone. • If RV2 has the right of way: o RV2's trajectory through the intersection is estimated using: ▪ RV2's location and dynamics ▪ RV2's turn signal state ▪ Lane designations and geometry ▪ Intersection geometry o HV's trajectory through the intersection is estimated using: ▪ HV's location ▪ HV's estimated acceleration ▪ Lane designations and geometry ▪ Intersection geometry o If there is a risk of collision based on the estimated trajectories of HV and RV2 then: ▪ HV is warned of a risk of collision with RV2 approaching from the right • Otherwise if HV has the right of way: o RV2's stopping distance is estimated using: ▪ RV2's location and dynamics ▪ Lane designations and geometry ▪ Intersection geometry ▪ Road conditions (if available) o If there is a risk that RV2 cannot stop before the intersection: ▪ HV is warned of a risk of collision with RV2 approaching from the right
Alternative Event Flow	• RV3 is in the "Oncoming Traffic" scenario application zone. • If RV3 has the right of way: o RV3's trajectory through the intersection is estimated using: ▪ RV3's location and dynamics ▪ RV3's turn signal state ▪ Lane designations and geometry ▪ Intersection geometry o HV's trajectory through the intersection is estimated using: ▪ HV's location ▪ HV's estimated acceleration ▪ Lane designations and geometry ▪ Intersection geometry o If there is a risk of collision based on the estimated trajectories of HV and RV3 then: ▪ HV is warned of a risk of collision with oncoming RV3 • Otherwise if HV has the right of way:

	○ RV3's trajectory and stopping distance is estimated using: ▪ RV3's location and dynamics ▪ RV3's turn signal state ▪ Lane designations and geometry ▪ Intersection geometry ▪ Road conditions (if available) ○ If there is a risk that RV3 cannot stop before the intersection: ▪ HV is warned of a risk of collision with oncoming RV3
Post-Conditions	• HV is aware of a risk of collision with RV1 approaching from the left. • HV is aware of a risk of collision with RV2 approaching from the right. • HV is aware of a risk of collision with oncoming RV3.
Service-Level KPIs	• Location accuracy. • Information age. • Communication range.
Information Requirements	• HV's location. • HV's turn signal state. • HV's estimated acceleration from stopped. • RV1's location and dynamics. • RV1's turn signal state. • RV2's location and dynamics. • RV2's turn signal state. • RV3's location and dynamics. • RV3's turn signal state. • Lane designations and geometry. • Intersection geometry. • Traffic stop signs. • Traffic light signal phase and timing. • Traffic rules and laws for three-way stops, four-way stops and unsigned intersections. • Current road conditions (if available).

User Story	**Detailed description and specifics**
User Story #1	Two vehicles are approaching an intersection (as described in main event flow). The vehicles determine the risk for a collision based on the vehicles' estimated trajectories.
User Story #2	
.....	

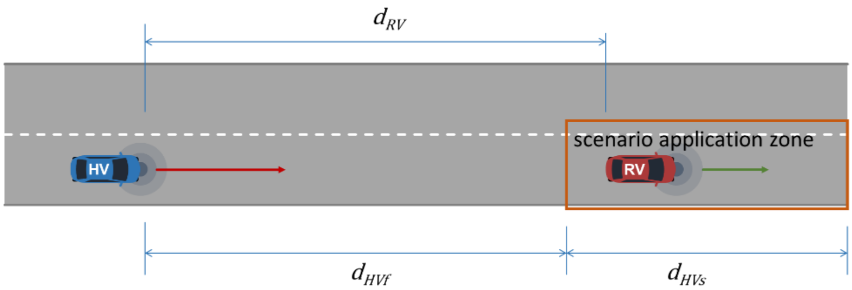
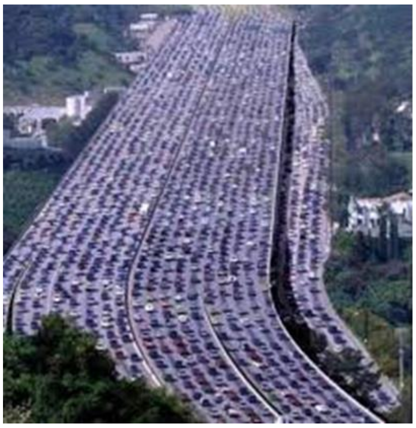
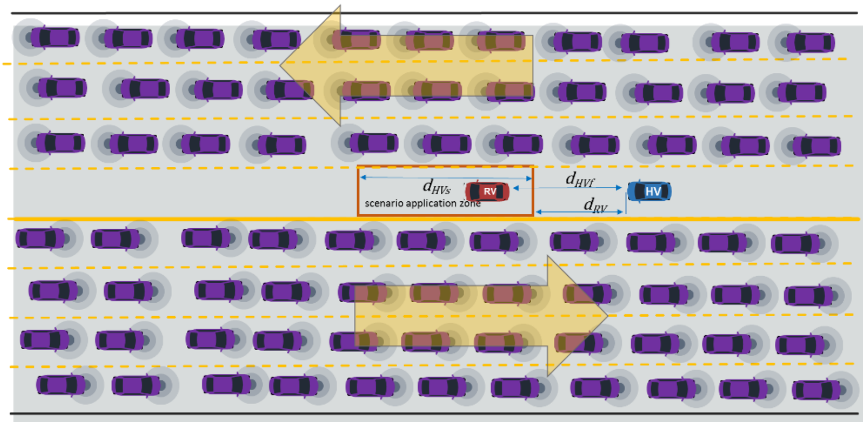
User Story #1			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Min. 100	Braking distance from 100 km/h, e.g. at an intersection on a rural road.

Information Requested/Generated	**Quality of information/ Information needs**	BSM or CAM (around 300 bytes)	Calculate trajectories based on exchanged data in BSM or CAM. Changes in kinematics of involved vehicles might require this information to be updated (or shared periodically) within the boundaries given by the Service Level Latency.
Service Level Latency	**[ms]**	100	Not highly time critical, but should stay below 100 ms to be effective/comparable to other ADAS.
Service Level Reliability		High/99.99 %	Needs to reliably allow for trajectory calculation to avoid collisions.
Velocity	**[m/s]**	28	Assuming speeds up to 100 km/h.
Vehicle Density	**[vehicle/km^2]**	10,000	Maximum assumed density in urban situation.
Positioning Accuracy	**[m]**	1.5 (3 σ)	Required for accurate trajectory calculation and collision risk estimation in relation to vehicle size.
Interoperability /Regulatory/Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

6.1.3 Emergency Brake Warning

Use Case Name	Emergency Brake Warning.
User Story	Alert HV that a lead RV is undergoing an emergency braking event.
Category	Safety.
Road Environment	Urban | Rural | Highway
Short Description	• Alert HV if a lead vehicle is braking.
Actors	• Host vehicle (HV). • Remote vehicle (RV).
Vehicle Roles	• HV represents the vehicle approaching the lead vehicle from behind. • RV1 represents the lead vehicle that has applied its brakes.
Road and Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	• Avoid a rear end collision between HV and RV.
Needs	• HV needs to know if there is an emergency braking event in RV.

Constraints/ Presumptions	• Assumptions will be required for the following information:
	  ○ HV's safe following distance
	  ○ HV's safe stopping distance

	○ RV's safe stopping distance is same as HV's
Geographic Scope	Global.
Illustrations	Emergency Brake Warning – No Congestion  Illustration of high congestion   Emergecny Brake Warning - Congestion  • d_{RV} = distance between HV and RV • d_{HVf} = safe following distance of HV • d_{HVs} = safe stopping distance of HV
Pre-Conditions	• HV is following RV. • The "Emergency Brake Warning" scenario application zone is determined from: ○ HV's location and dynamics ○ HV's safe following distance ○ HV's safe stopping distance ○ Lane designations and geometry ○ Current road conditions (if available)

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

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

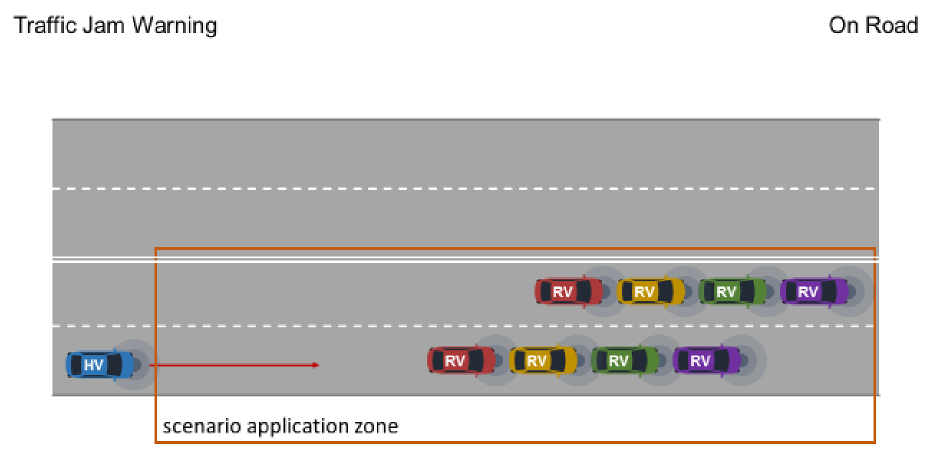
User Story #1			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	360	Under the assumptions of Vrv=25 m/s, Vhv=50 m/s and a=0.4g this is the minimum distance (400 ms margin or 20 m) at which HV needs to be warned to avoid collision.
Information Requested/Generated	**Quality of information/ Information needs**	BSM or CAM (between 200-400 bytes)	The message should be delivered to HV. It contains the information about the hard-braking event at RV. It contains other information regarding RV such as location, velocity, acceleration, etc.
Service Level Latency	**[ms]**	120	Ideally, the information about the hard-braking event should be conveyed as soon as possible. Examining current radar and camera vision sensors the detection times are 100-300 ms which makes V2X latency within the same budget. Additionally, for the reliability that we

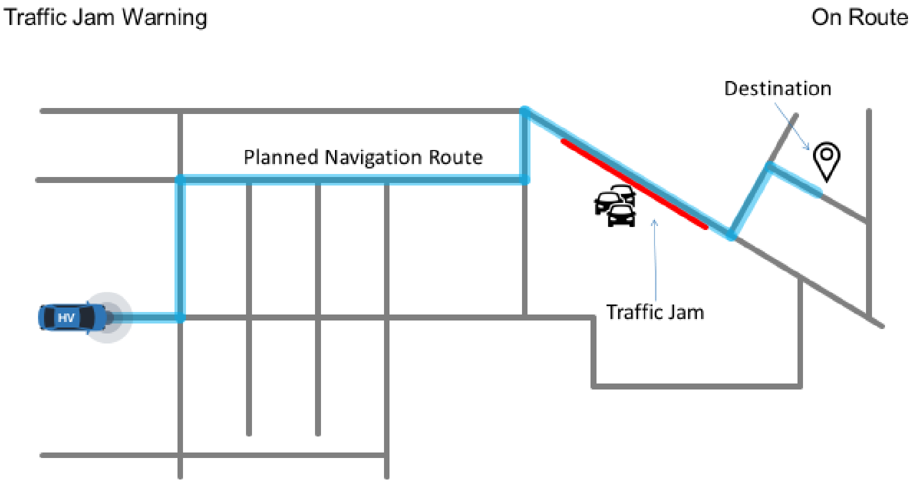
			are requesting this latency seems reasonable. For example, the latency of 100 ms causes the HV to travel additional 5 m before final stop at 50 m/s initial velocity, however, this additional distance is budgeted in the range estimate. This includes handling, access, and OTA latency.
Service Level Reliability		99.99 %	The hard-braking event message needs to be delivered to the HV with high reliability.
Velocity	**[m/s]**	50	
Vehicle Density	**[vehicle/km^2]**	10,000	Assume maximum density.
Positioning Accuracy	**[m]**	1.5 (3σ)	HV needs to know whether the hard-braking vehicle in the front is in the same lane.
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	Yes	Interoperability needs to be in place for HV to receive a message from RV.

User Story #2			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	290	Under the assumptions of Vrv=25 m/s, Vhv=50 m/s, 0.5 second reaction time and a=0.4g (and 300 ms margin or 15 m) this is the minimum distance at which the Level 3 system needs to be warned to avoid collision.
Information Requested/Generated	**Quality of information/ Information needs**	BSM or CAM (between 200-400 bytes)	The message should be delivered to HV. It contains the information about the hard-braking event at RV. It contains other information regarding RV such as location, velocity, acceleration, etc.
Service Level Latency	**[ms]**	120	Reasonable latency in the context of the other existing sensor systems as well as taking into account the high reliability needed.
Service Level Reliability		99.99 %	The hard-braking event message needs to be delivered to the HV with high reliability.
Velocity	**[m/s]**	50	
Vehicle Density	**[vehicle/km^2]**	10,000	Assume maximum density.

Positioning Accuracy	**[m]**	1.5 (3σ)	HV needs to know whether the hard-braking vehicle in the front is in the same lane.
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	Yes	Interoperability needs to be in place for HV to receive a message from RV.

6.1.4 Traffic Jam Warning and Route Information

Use Case Name	Traffic Jam Warning and Route Information.
User Story	Alert HV of an approaching traffic jam.
Category	Safety.
Road Environment	Urban | Rural | Highway
Short Description	• Warn HV of an approaching traffic jam on the road. • Notify HV of a traffic jam on the navigation route.
Actors	• Host vehicle (HV). • Remote vehicle (RV).
Vehicle Roles	• HV represents vehicle approaching traffic jam. • RVs represent remote vehicles caught in traffic jam.
Road & Roadside Infrastructure Roles	Roads are defined by their lane designations and geometry.
Other Actors' Roles	NA
Goal	Alert HV of approaching traffic jam.
Needs	HV need to be aware of approaching traffic jam and its geometry.
Constraints/ Presumptions	• NA
Geographic Scope	Global.
Illustrations	

Pre-Conditions	• HV is moving forward.
	• Known traffic jam is defined by its location and geometry.
	• The "On Road" scenario application zone is determined from:
	  ○ HV's location and dynamics
	  ○ HV's safe stopping distance
	  ○ lane designations and geometry
	  ○ road conditions (if available)
	• The "On Route" scenario application zone is determined from:
	  ○ HV's location
	  ○ HV's planned navigation route

Main Event Flow	• If the traffic jam's location is in the "On Road" scenario application zone: ○ Warn HV of the approaching traffic jam
Alternate Event Flow	• If the traffic jam's location is in the "On Route" scenario application zone: ○ Notify HV of the traffic jam location and geometry
Post-Conditions	• HV is aware of the approaching traffic jam on the road. • HV is aware of the traffic jam's location and geometry on the navigation route.
Service Level Key Performance Indicators	• Communications range. • Age of information. • Position accuracy.
Information Requirements	• HV's location and dynamics. • HV's safe stopping distance. • HV's planned navigation route (if available). • Lane designations and geometry. • Traffic jam's location and geometry.

User Story #1 Urban Scenario on Road Warning			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	1000	Warn early enough to safely brake when approaching the traffic jam. Calculation based on the duration of a traffic jam and the possibility for it to still exist when a

			vehicle driving on its way with an average speed is reaching the jam (duration 2 h, speed 50 km/h).
Information Requested/Generated	**Quality of information/ Information needs**	Uplink BSM or DENM	Get traffic jam information from BSM or DENM, or from other (backend) services. Size usually around 300 bytes.
Service Level Latency	**[ms]**	2000	Traffic jams are normally not happening within a very short time period. If communication range is big enough, e.g. on a highway 2 s driving with 150 km/s means 80 m. Jam should be visible if you are as close as 80 m in urban environment (50 km/h), 2 s means 26 m, which should be close enough to see the jam
Service Level Reliability		Medium 50 %	Normally, a traffic jam contains several cars. Assuming an equipment rate of 20 % and an average of at least 10 cars per jam means that there are at least 2 cars which send the message in parallel.
Velocity	**[m/s]**	14	Assuming typical maximum allowed speeds and some safety (50 km/h).
Vehicle Density	**[vehicle/km^2]**	10,000	Max assumed density in urban situation.
Positioning Accuracy	**[m]**	< 20	As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than LoS the given values seem reasonable.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

User Story #2 Rural Scenario on Road Warning			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	1000	Warn early enough to safely brake when approaching the traffic jam. Calculation based on the duration of a traffic jam and the possibility for it to still exist when a vehicle driving on its way with an average speed is reaching the jam (duration 2 h, speed 50 km/h, 100 km/h 150 km/h).

Information Requested/Generated	**Quality of information/ Information needs**	Uplink BSM or DENM	Get traffic jam information from BSM or DENM, or from other (backend) services. Size usually around 300 bytes.
Service Level Latency	**[ms]**	2000	Traffic jams are normally not happening within a very short time period. If communication range is big enough e.g. on a highway 2 s driving with 150 km/s means 80 m. Jam should be visible if you are as close as 80 m in urban environment (50 km/h), 2 s means 26 m which should be close enough to see the jam
Service Level Reliability		Medium 50 %	Normally, a traffic jam contains several cars. Assuming an equipment rate of 20 % and an average of at least 10 cars per jam means that there are at least 2 cars which send the message in parallel.
Velocity	**[m/s]**	28	Assuming typical maximum allowed speeds and some safety (100 km/h).
Vehicle Density	**[vehicle/km^2]**	500	Maximum assumed density in rural situation.
Positioning Accuracy	**[m]**	< 20	As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than LoS the given values seem reasonable.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

User Story #3 Highway Scenario on Road Warning			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	1000	Warn early enough to safely brake when approaching the traffic jam. Calculation based on the duration of a traffic jam and the possibility for it to still exist when a vehicle driving on its way with an average speed is reaching the jam (duration 2 h, speed 50 km/h, 100 km/h 150 km/h).

Information Requested/Generated	**Quality of information/ Information needs**	Uplink BSM or DENM	Get traffic jam information from BSM or DENM, or from other (backend) services. Size usually around 300 bytes.
Service Level Latency	**[ms]**	2000	Traffic jams are normally not happening within a very short time period. If communication range is big enough e.g. on a highway 2 s driving with 150 km/s means 80 m. Jam should be visible if you are as close as 80 m in urban environment (50 km/h), 2 s means 26 m which should be close enough to see the jam.
Service Level Reliability		Medium 50 %	Normally, a traffic jam contains several cars. Assuming an equipment rate of 20 % and an average of at least 10 cars per jam means that there are at least 2 cars which send the message in parallel.
Velocity	**[m/s]**	42	Assuming typical maximum allowed speeds and some safety (150 km/h).
Vehicle Density	**[vehicle/km^2]**	5000	Maximum assumed density in highway situation.
Positioning Accuracy	**[m]**	< 20	As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than LoS the given values seem reasonable.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

User Story #1 Urban Scenario on Route Information			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	100,000	Warn early enough to safely brake when approaching the traffic jam. Calculation based on the duration of a traffic jam and the possibility for it to still exist when a vehicle driving on its way with an average speed is reaching the jam (duration 2 h, speed 50 km/h).

Information Requested/Generated	**Quality of information/ Information needs**	Uplink BSM or DENM	Get traffic jam information from BSM or DENM, or from other (backend) services. Size usually around 300 bytes.
Service Level Latency	**[ms]**	Minutes	Traffic jams are normally not happening within a very short time period. If communication range is big enough e.g. on a highway 2 seconds driving with 150 km/s means 80 m. Jam should be visible if you are as close as 80 meters in urban environment (50 km/h), 2 s means 26 m which should be close enough to see the jam
Service Level Reliability		Medium 50 %	Normally, a traffic jam contains several cars. Assuming an equipment rate of 20 % and an average of at least 10 cars per jam means that there are at least 2 cars which send the message in parallel.
Velocity	**[m/s]**	14	Assuming typical maximum allowed speeds and some safety (50 km/h).
Vehicle Density	**[vehicle/km^2]**	10000	Maximum assumed density in urban situation.
Positioning Accuracy	**[m]**	< 20	As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than LoS the given values seem reasonable.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

User Story #2 Rural Scenario on Route Information			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	200,000	Warn early enough to safely brake when approaching the traffic jam. Calculation based on the duration of a traffic jam and the possibility for it to still exist when a vehicle driving on its way with an average speed is reaching the jam (duration 2 h, speed 50 km/h, 100 km/h 150 km/h)

Information Requested/Generated	**Quality of information/ Information needs**	Uplink BSM or DENM	Get traffic jam information from BSM or DENM, or from other (backend) services. Size usually around 300 bytes.
Service Level Latency	**[ms]**	Minutes	Traffic jams are normally not happening within a very short time period. If communication range is big enough e.g. on a highway 2 s driving with 150 km/s means 80 m. Jam should be visible if you are as close as 80 m in urban environment (50 km/h), 2 s means 26 m which should be close enough to see the jam.
Service Level Reliability		Medium 50 %	Normally, a traffic jam contains several cars. Assuming an equipment rate of 20 % and an average of at least 10 cars per jam means that there are at least 2 cars which send the message in parallel.
Velocity	**[m/s]**	28	Assuming typical maximum allowed speeds and some safety (100 km/h).
Vehicle Density	**[vehicle/km^2]**	500	Maximum assumed density in rural situation.
Positioning Accuracy	**[m]**	< 20	As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than LoS the given values seem reasonable.
Interoperability Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

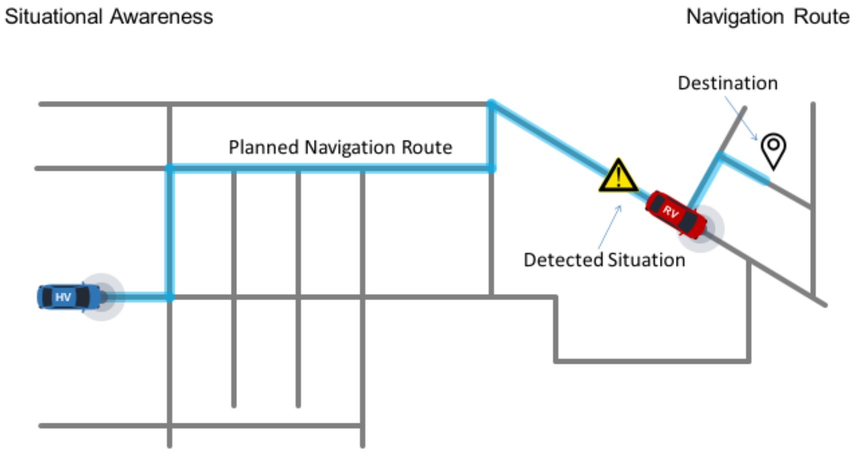
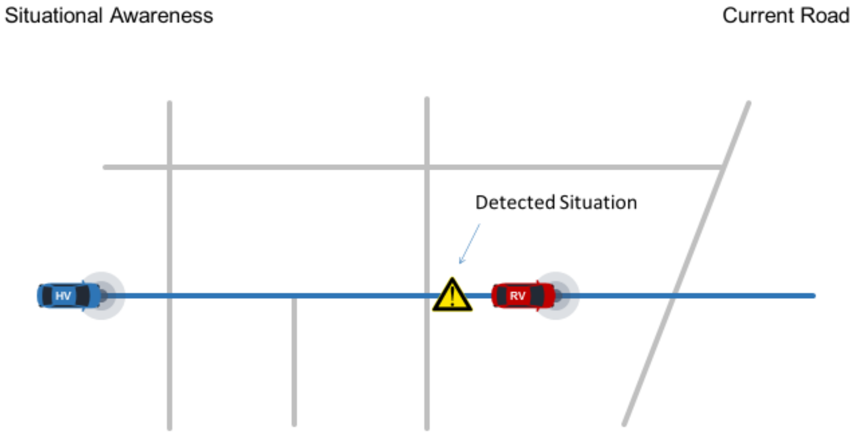
User Story #3 Highway Scenario on Route Information			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	300,000	Warn early enough to safely brake when approaching the traffic jam. Calculation based on the duration of a traffic jam and the possibility for it to still exist when a vehicle driving on its way with an average speed is reaching the jam (duration 2 h, speed 50 km/h, 100 km/h 150 km/h)

Information Requested/Generated	**Quality of information/ Information needs**	Uplink BSM or DENM	Get Traffic jam information from BSM or DENM, or from other (backend) services. Size usually around 300 bytes.
Service Level Latency	**[ms]**	Minutes	Traffic jams are normally not happening within a very short time period. If communication range is big enough e.g. on a highway 2 s driving with 150 km/s means 80 m. Jam should be visible if you are as close as 80 m in urban environment (50 km/h), 2 s means 26 m which should be close enough to see the jam.
Service Level Reliability		Medium 50 %	Normally, a traffic jam contains several cars. Assuming an equipment rate of 20 % and an average of at least 10 cars per jam means that there are at least 2 cars which send the message in parallel.
Velocity	**[m/s]**	42	Assuming typical maximum allowed speeds and some safety (150 km/h).
Vehicle Density	**[vehicle/km^2]**	5000	Maximum assumed density in highway situation.
Positioning Accuracy	**[m]**	< 20	As there is the assumption that the jam is not something very spontaneous and as the warning is meant for areas higher than LoS the given values seem reasonable.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

6.1.5 Real-Time Situational Awareness and High-Definition Maps: Hazardous Location Warning

Use Case Name	Real-Time Situational Awareness and High-Definition Maps.
User Story	An autonomous or semi-autonomous vehicle is driving on a road (route), heading towards a road segment, which presents unsafe and unknown conditions ahead. A host vehicle is made aware of situations detected and shared by remote vehicles. Situations may include such things as accidents, weather, traffic, construction.
Category	Safety | Automated Driving
Road Environment	Urban | Rural | Highway
Short Description	A host vehicle is made aware of accidents, traffic, adverse weather, road conditions, construction and other situations detected and shared by remote vehicles. The shared situations are relevant along the host vehicle's navigation route or current road of travel. Some examples include but are not limited to:

	• Traffic congestion detected by slowly-moving RVs. • Adverse weather conditions detected by temperature changes and wiper activation. • Accidents detected by air bag deployment events. • Slippery road conditions detected by traction control events. • Disabled vehicles detected by hazard lamps or tyre pressure.
Actors	• Remote vehicle (RV). • Host vehicle (HV).
Vehicle Roles	• RV represents the vehicle detecting and sharing situational information. • HV represents the vehicle made aware of situational information.
Road and Roadside Infrastructure	Roads are defined by their lane designations and geometry.
Other Actors' Roles	Traffic management: An entity that collects accidents, traffic, adverse weather, road conditions, construction and other situations and reports them to other vehicles. (For User Story 2, not for 1).
Goal	Alert HV of a situation that lies ahead along its navigation route or current road segment.
Needs	HV needs to be aware of a situation that lies ahead along its navigation route or road segment.
Constraints/ Presumptions	The "Navigation Route" scenario includes all roads ahead along HV's known navigation route. The "Current Road" scenario includes the length of the road ahead that HV is currently travelling on.
Geographic Scope	Everywhere.

Illustrations	 
Pre-Conditions	One or more RV's have detected conditions that constitute a situation that HV should be made aware of.
Main Event Flow	If the situation's location is on HV's navigation route: • One or more RV's have reported conditions to the Traffic Management entity that constitute a situation that one or more HVs should be made aware of. • HV is made aware of the situation's nature and location. (cf. User Story #2)
Alternate Event Flow	If the situation's location is ahead along HV's current road of travel: • One or more RV's detect a situation that one or more HVs should be made aware of. • The RV(s) provide the notification to the HV(s). • HV is made aware of the situation's nature and location.
Post-Conditions	HV is made aware of a detected situation along its navigation route or current road ahead.
Service Level KPIs	• Service Level Latency. • Service Level Reliability. • Information requested/generated. • Velocity. • Vehicle density. • Positioning accuracy.
Information Requirements	• RV's location and dynamics. • RV's wiper, lamps status. • RV's outside temperature, barometric pressure. • RV's hazard lamps, tyre pressure. • RV's ABS, stability control, traction control, airbag events. • Road map. • HV's navigation route.

	• Road conditions. • Construction zone map.

User Story	Detailed description, specifics and main differences to the User Story in the main template
HV only supported by RVs	A remote vehicle (RV) is driving on the road and approaches a dangerous area which is detected by using RV's sensors. The HV might drive behind the RV in the same direction, or in front of the RV in the opposite direction, so towards the area where the RV has detected the dangerous situation. RVs detecting such dangerous situations will broadcast information about them to other vehicles, e.g. the HV. The HV or HV driver can assume appropriate actions after having received the awareness information.
HV receives information from a backend/cloud	This Use Case mainly refers to a real-time HD map update service. The HV is receiving information that is relevant for the road/route ahead from a backend, containing information that might allow the HV to adjust its route accordingly. The traffic management mentioned in 'Other Actors' Roles' could play a role here.

The following table provides the specific requirements for the above User Story.

HV only supported by RVs			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	300 – physical limit	Communication is only done by vehicles in the vicinity of the HV. It is limited to the range of physical transmission.
Information Requested/Generated	**Quality of information/ Information needs**	300 Bytes	Normal size of CAM/BSM should be enough, maybe containing fields indicating common types of critical situations that lie ahead. Transmission of detailed object information is not needed. Standard transmission rate of 10 Hz should be enough.
Service Level Latency	**[ms]**	100	Driving with 120 km/h, 300 m (minimum communication range) will take just short of 10 s, so 100 ms for the car to react should be enough.
Service Level Reliability		99 %	The HV could aggregate warnings from several RVs, each individual RVs reliability thus does not have to be too high.

Velocity	**[m/s]**	70	~250 km/h – Max speed on highways, also realistic for relative speeds of HV and RV driving in different directions.
Vehicle Density	**[vehicle/km^2]**	1500	Standard assumption on vehicle density.
Positioning Accuracy	**[m]**	0.5 < 5	Typical positioning accuracy to confirm traffic lane. For non-lane-specific information, less accurate localisation is acceptable.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Inter-OEM-operability must be assured.

HV receives information from a backend/cloud			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	~30,000	Situations are relevant along a navigation route or along a road if a navigation route is not known. Depends on the needs for efficient re-routing.
Information Requested/Generated	**Quality of information/ Information needs**	300-1000 Bytes	From the backend, the HV will receive information (events, or vector data), not raw data. Some details are needed, but still no need for detailed object descriptions or the like.
Service Level Latency	**[ms]**	1-2 s / 10-200 s	Information may need to be aggregated from multiple RVs before a situation is identified.1-2 s for safety-related information concerning the vicinity of the HV; 10-200 s for general information about route obstructions or the like further ahead, in order to make timely rerouting possible.
Service Level Reliability		99 % Low	For safety-related information, timely and reliable communication is decisive. In the backend, data of several vehicles is aggregated, so the single vehicle's data has to be moderately reliable. For rerouting information, this should be enough.
Velocity	**[m/s]**	70	~250 km/h – Max speed on highways.
Vehicle Density	**[vehicle/km^2]**	1500	Standard assumption on vehicle density.

Positioning Accuracy	**[m]**	0.5 < 5	Typical positioning accuracy to confirm traffic lane. For non-lane-specific information, less accurate localization is acceptable.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Inter-vendor-operability must be assured.

6.1.6 Cooperative Lane Change (CLC) of Automated Vehicles: Lane Change Warning

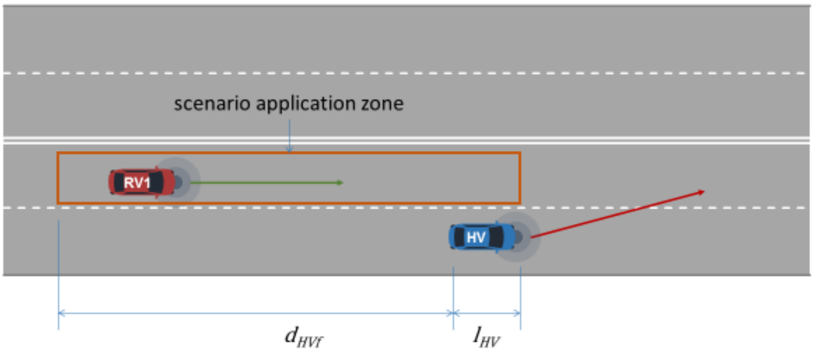
Use Case Name	Lane Change Warning.
User Story	Host vehicle (HV) signals an intention to change lanes.
Category	Safety.
Road Environment	Urban | Rural | Highway
Short Description	• Alert HV intending to change lanes of a lack of space or risk of collision with a lagging RV1 approaching from behind in the target lane. • Alert HV intending to change lanes of a lack of space or risk of collision with a leading RV2 in the target lane. • Alert HV intending to change lanes that this manoeuvre is not permitted on the current road segment.
Actors	• Host vehicle (HV). • Remote vehicle 1 (RV1). • Remote vehicle 2 (RV2).
Vehicle Roles	• HV represents the vehicle intending to change lanes. • RV1 represents the lagging vehicle in the target lane. • RV2 represents the leading vehicle in the target lane.
Roadside Infrastructure Roles	• Roads are defined by their lane designations and geometry. • Road segments indicate where changing lanes is not permitted.
Other Actors' Roles	Not applicable.
Goal	Avoid HV encroaching into RV2; avoid HV encroaching into RV1.
Needs	• HV needs to know if there is a lack of space or risk of collision with a lagging RV1 in the target lane. • HV needs to know if there is a lack of space or risk of collision with a leading RV2 in the target lane. • HV needs to know if a lane change is not permitted on the current road segment.

Constraints/ Presumptions	• Assumptions will be required for the following information:
	  ○ HV's safe following distance
	  ○ RV1's safe following distance is the same as HV's.

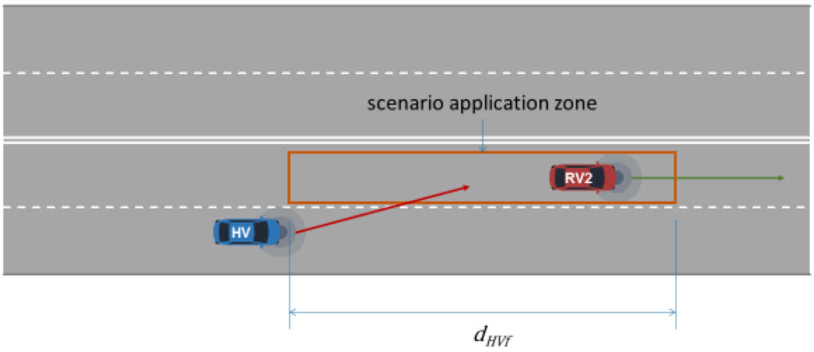
Geographic Scope	Global.

Illustrations

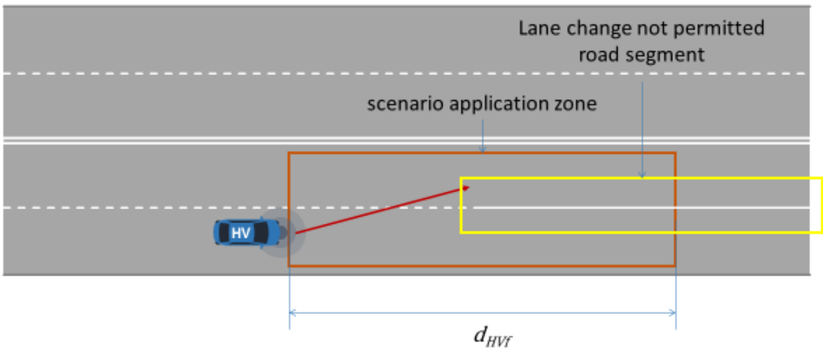
Lane Change Warning — Lagging Vehicle



Lane Change Warning — Leading Vehicle



Lane Change Warning — Not Permitted



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

Pre-Conditions	• HV has signalled its intention to change lanes.
	• Known road segments define is passing is not permitted.
	• The "Lagging Vehicle" scenario application zone is determined from:
	    o HV's location and dynamics
	    o HV's length
	    o HV's safe following distance
	    o Lane designations and geometry
	    o Road conditions (if available)
	• The "Leading Vehicle" scenario application zone is determined from:
	    o HV's location and dynamics
	    o HV's safe following distance
	    o Lane designations and geometry
	    o Road conditions (if available)

Main Event Flow	• If RV1 is in the "Lagging Vehicle" scenario application zone:
	    o If the trajectory of RV1 and HV cross:
	        ▪ Warn HV of the risk of collision with RV1
	    o Otherwise:
	        ▪ Alert HV of the lack of space to safely complete the manoeuvre

Alternative Event Flow [2]	• If RV2 is in the "Leading Vehicle" scenario application zone:
	    o If the trajectory of RV2 and HV cross:
	        ▪ Warn HV of the risk of collision with RV2
	    o Otherwise:
	        ▪ Alert HV of the lack of space to safely complete the manoeuvre.

Post-Conditions	• HV is aware of a lack of space or of a risk of collision with a lagging RV1 in the target lane. • HV is aware of a lack of space or of a risk of collision with a leading RV2 in the target lane. • HV is aware of whether a lane change is permitted or not on the current road segment.
Service Level Requirements	• Positioning accuracy. • Information age. • Communication range. • Duration of the communication.
Information Requirements	• HV's location and dynamics. • HV's length. • HV's safe following distance. • RV1's location and dynamics. • RV2's location and dynamics. • Lane designations and geometry. • Road segment lane change rules. • Road conditions (if available).

User Story #1 (Lane change warning – lagging vehicle{:RV1_v>HV_v}, High Way)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**

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

Range	**[m]**	83	The range is derived from the different between HV(100 km/h) and RV1(120 km/h) speeds.
Information Requested/Generated	**Quality of information/ Information needs**	Approx. 300 B per message/high QoS	Speed, GNSS location, past trajectory, turn sign ON and side, like BSM frame messaging.
Service Level Latency	**[ms]**	400	Depends on the number of repetitions and message cadence.
Service Level Reliability		99.9 %	A Service Level Reliability this high should be enough to allow perceived zero-error appearance of the lane change. False positives are more problematic than false negatives.
Velocity	**[m/s]**	HV: 28 RV1: 33	Varies between Rural |Urban |HW. But more important for this UC is the speed difference between the HV and RV.
Vehicle Density	**[vehicle/km^2]**	4500	See calculation in the table App. 5[8.5].
Positioning Accuracy	**[m]**	1.5	In order to perform lane-accurate positioning, a positioning accuracy of around 1.5 m should be provided.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Interoperability between different OEMs is needed. Every vehicle should make its presence known periodically (as a broadcast). Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood.

User Story #2 (Lane change warning –leading vehicle {: HV_v>RV2_v}, Urban)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	28	The range is derived from the different between the HV and RV speeds.
Information Requested/ Generated	**Quality of information/ Information needs**	Approx. 300 B per message/high QoS	Speed, GNSS location, past trajectory, turn sign ON and side, like BSM frame messaging.
Service Level Latency	**[ms]**	400	Depends on the number of repetitions and message cadence.

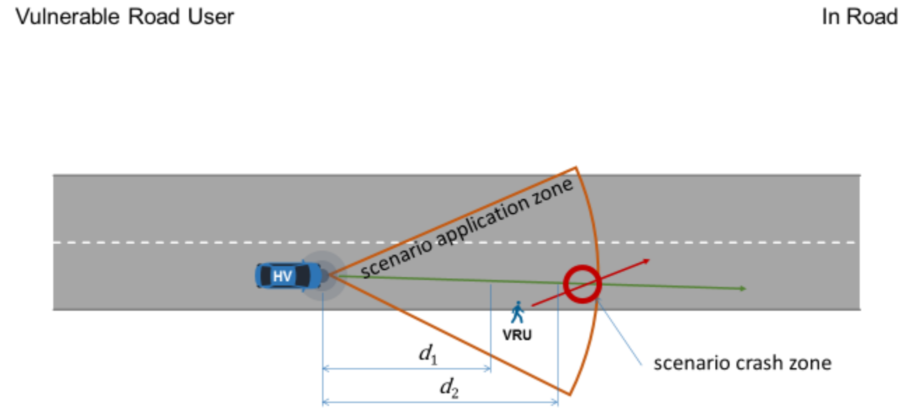
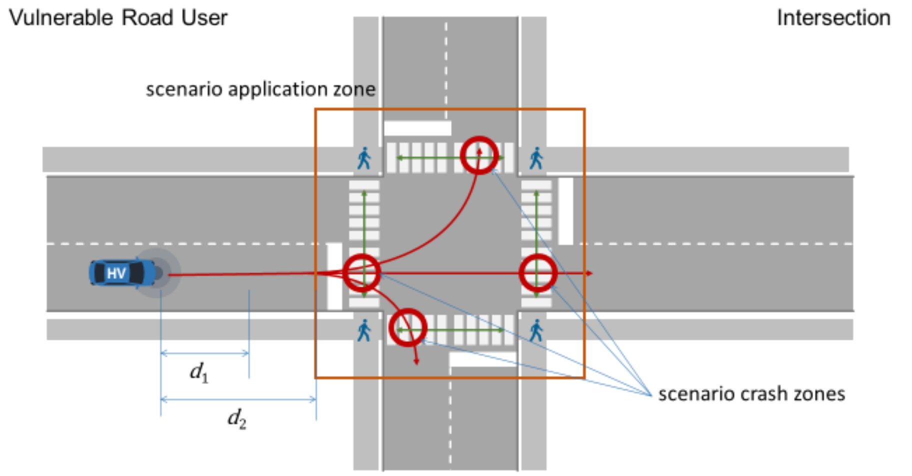
Service Level Reliability		99.9 %	A service level reliability this high should be enough to allow perceived zero-error appearance of the lane change. False positives are more problematic than false negatives.
Velocity	**[m/s]**	RV2: 11 HV: 14	Varies between Rural |Urban |HW. But more important for this UC is the speed difference between the HV and RV.
Vehicle Density	**[vehicle/km^2]**	12,000	See calculation in the table App. 5[8.5].
Positioning Accuracy	**[m]**	1.5	In order to perform lane-accurate positioning, a positioning accuracy of around 1.5m should be provided.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes/Yes/Yes	Interoperability between different OEMs is needed. It should be regulated that every vehicle has to make its presence known periodically (as a broadcast). Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood.

User Story #3 (Lane change warning –Not Permitted {: T_Maneuver>T_safe}, Rural)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	51	The range is derived from the different between the HV and RV speeds,
Information Requested/Generated	**Quality of information/ Information needs**	Approx. 300 B per message/high QoS	Speed, GNSS location, past trajectory, turn sign ON and side, like BSM frame messaging.
Service Level Latency	**[ms]**	400	Depends on the number of repetitions and message cadence.
Service Level Reliability		99.9 %	A service level reliability this high should be enough to allow perceived zero-error appearance of the lane change. False positives are more problematic than false negatives.
Velocity	**[m/s]**	HV: 23	Varies between Rural |Urban |HW. But more important for this UC is the speed difference between the HV and RV.

Vehicle Density	**[vehicle/km^2]**	9000	See calculation in the table App. 5[8.5].
Positioning Accuracy	**[m]**	1.5	In order to perform lane-accurate positioning, a positioning accuracy of around 1.5 m should be provided.
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	Yes / Yes / Yes	Interoperability between different OEMs is needed. It should be regulated that every vehicle has to make its presence known periodically (as a broadcast). Standardisation is required in the sense that the format for trajectories should be common to all so that they can be fully understood.

6.1.7 Vulnerable Road User

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

Illustrations	  • d_1 = stopping distance of HV • d_2 = distance from HV to scenario crash zone

Pre-Conditions	• HV is moving forward.
	• Before establishment of LoS, if any.
	• Known VRU is characterised (bike, pedestrian, motorcycle,…)
	• The "In Road" scenario application zone is determined from:
	  ○ HV's location and dynamics
	  ○ HV's safe stopping distance
	  ○ Lane designations and geometry
	  ○ Road conditions (if available)
	• The "Intersection" scenario application zone is determined from:
	  ○ HV's location and dynamics
	  ○ HV's safe stopping distance
	  ○ Intersection geometry
	  ○ Road conditions (if available)

Main Event Flow	• If VRU is in the "On Road" scenario application zone:
	  ○ If HV's trajectory and VRU's trajectory are on a collision course then:
	    ▪ Warn HV of the risk of collision with the approaching VRU
	  ○ Otherwise:
	    ▪ Caution HV of the approaching VRU

Alternative Event Flow	• If VRU is in the "Intersection" scenario application zone;
	  ○ If HV's trajectory and VRU's trajectory are on a collision course then
	    ▪ Warn HV of the risk of collision with the approaching VRU
	  ○ Otherwise
	    ▪ Caution HV of the approaching VRU

Post-Conditions	• HV/Driver is aware of its approach towards the VRU and any risk of collision (Day 1-1.5). • HV is aware of its approach towards the VRU and takes the necessary safety measures to avoid or mitigate collision (Day 3).
Service Level Requirements	• Positioning accuracy. • Information age. • Communications range.
Information Requirements	• HV's location and dynamics. • HV's safe stopping distance. • VRU's location and dynamics. • VRU's characterisation (bike, pedestrian, motorcycle,…) • Lane designations and geometry. • Intersection geometry. • Current road conditions (if available). • Other vehicle sensor data.

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

Awareness of the presence of VRUs near potentially dangerous situations	This VRU User Story describes a scenario in which a presence warning at crossings and spots without line-of-sight (LOS), e.g. automatic detection of pedestrians waiting and/or crossing from infrastructure is intended. VRUs are watched via infrastructure support as surveillance cameras/wireless detection mechanisms and/or are equipped with mobile VRU devices (UE). Awareness notifications are shared with drivers e.g. via roadside units/monitoring system attached to a 3GPP system (e.g. potentially using MEC) sending messages to drivers or drivers C-ITS systems monitor actively VRUs that are equipped with a device.
	
	The User Story involves one or multiple vehicles and it assumes V2I and/or V2P connectivity.
	
	In this User Story a vehicle has entered an area in which VRUs are present.
	
	• The area could be crossings (incl. cross-walks, zebra crossings) and spots without line-of-sight (LOS).
	• VRUs are watched via infrastructure support as surveillance cameras/wireless detection mechanisms and/or are equipped with mobile VRU devices (UE).
	• Awareness notifications are shared with drivers, for example via:
	  ○ Roadside units
	  ○ Monitoring systems attached to a 3GPP system (extension of User Story, e.g. potentially using MEC) sending messages to drivers or vehicle's C-ITS system, and actively monitoring VRUs that are equipped with a device

Collision risk warning	This VRU User Story describes a scenario in which a collision prevention at crossings and spots without LOS, e.g. automatic detection of pedestrians waiting and/or crossing from infrastructure is intended.
	
	In this VRU User Story the accuracy, performance and functionality of VRU devices incl. UEs is sufficient for collision risk detection, and vehicles share the information collected by sensors with each other.
	
	Vehicles have entered an area in which VRUs are present.
	
	• The area could be crossings (incl. cross-walks, zebra crossings) and spots without line-of-sight.
	• VRUs are watched via infrastructure support as surveillance cameras/wireless detection mechanisms and/or are equipped with mobile VRU devices (UE).
	• VRUs are watched via information collected by vehicles sensors and relevant information is shared with other vehicles and/or road site units.
	• Warning notifications are shared with drivers, for example via:
	  ○ Roadside units
	  ○ Monitoring systems attached to a 3GPP system (e.g. potentially using MEC) sending messages to drivers
	  ○ Other vehicle's C-ITS system based on sensor data
	  ○ Vehicle's C-ITS systems actively monitoring VRUs that are equipped with a device
	• Cooperative actions and manoeuvres are enabled via cooperative message exchange in a bi-directional manner.

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Awareness of the presence of VRUs near potentially dangerous situations			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Min. 80 a) Urban 150 b) Rural 300	For long distances we expect local sensors of the vehicle (electronic horizon) to be able to resolve VRU protection scenarios. We do not foresee that a full stop will be feasible in most VRU protection scenarios. It is rather to trigger an obstacle avoidance manoeuvre. Therefore, 40 m are roughly 2 s driving time when driving with 80 km/h should provide enough time to trigger an appropriate event.
Information Requested/Generated	**Quality of information/ Information needs**	Information quality: Surveillance: medium quality Safety: very high Data needs: Initially: 20-40 Mbps to enable	Surveillance: The data rate depends strongly on the capabilities of the different C-ITS systems to process received RAW data and generate information data. To allow all "sensor detected" data being shared we recommended initially a higher data rate. The end goal is to communicate only information/processed data.

		raw sensor sharing (e.g. from on-/off-board cameras). Later: around 2 Mbps since only information are shared	Safety: Vehicle needs information on the precise location of the VRUs in its vicinity and its own position in the near future. Initially, raw sensor data (e.g. from cameras) is shared, summing up to approx. 20-40 Mbps (H.264 compression assumed), cf. T-190069. Later, assuming 1 kB/VRU/100 ms for information transmission and 25 VRUs, we end up at 2 Mbps.
Service Level Latency	**[ms]**	100 Recommended communication latency: 20	This is the maximum latency tolerable for a reaction due to moving VRUs very near the road. 20 ms for VRU communication latency is comparable to that of cooperative manoeuvres and sensor sharing because we see that the VRU situations will occur much more unexpectedly and in close proximity to the vehicle. Thus, longer communication latencies would be adverse to the intended purpose. Justification: For a 50 km/hr drive in dense urban environments (80 m communication radius), the total time budget until a potential complete stop has to be initiated is approximately 3.96 s.
Service Level Reliability		99.9 %	High, the reliability here should be sufficient to guarantee QoS. 99.9 % should be sufficient, since additional vehicle sensors are in place that can help to avoid collisions.
Velocity	**[m/s]**	Urban: 22.22 Rural: 36.11	In urban areas, considering 80 km/h max. speed. In rural areas, considering 130 km/h max. speed.
Vehicle Density	**[vehicle/km^2]**	Concerned VRUs: ~300 total Present VRUs per km^2: ~10,000 Vehicles: 1500	Figures given only for urban areas, since we consider this as the more critical case with regards to vehicle number/density. VRUs concerned are those near streets, not counting workers in offices or the like. However, for total network load, etc., all VRUs in the given area have to be considered, or as many as the network can support.
Positioning Accuracy	**[m]**	1-2	In order to correct positioning based on GNSS (e.g. GPS, Galileo), this accuracy should be enhanced via the 3GPP System.

			The 3GPP System shall provide a positioning accuracy of 1-2 m, e.g. considering support of GNSS, highly accurately positioned RSU and CV2X UEs.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	In order to make it possible to share information and data on VRUs between vehicles, inter-OEM-operability should be guaranteed. Interoperability of UEs with RSUs, vehicles, and other local entities should also be guaranteed.

Collision risk warning			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Min. 80 a) Urban 150 b) Rural 300	Limited range for calculations = 80m, since this is the communication range in highly-dense metropolitan areas. For longer-distances we expect other local sensors of the vehicle (electronic horizon) to be able to assist in VRU protection scenarios. We do not foresee that a full stop will be feasible in most VRU protection scenarios. It is rather to trigger an obstacle avoidance manoeuvre. Therefore, 40 m are roughly 2 s driving time when driving with 80 km/h should provide enough time to trigger an appropriate event.
Information Requested/Generated	**Quality of information/ Information needs**	Information quality: Surveillance: medium quality Safety: very high Data needs: Initially: 20-40 Mbps to enable raw sensor sharing (e.g. from on-/off-board cameras). Later: around 2 Mbps since only information are shared.	Surveillance: The data rate depends strongly on the capabilities of the different C-ITS systems to process received RAW data and generate information data. To allow all “sensor detected” data being shared we recommended initially a higher data rate. Safety: Vehicle needs information on the precise location of the VRUs in its vicinity and its own position in the near future. Initially, raw sensor data (e.g. from cameras) is shared, summing up to approx. 20-40 Mbps (H.264 compression assumed), cf. T-190069.

			Later, assuming 1 kB/VRU/100 ms for information transmission and 25 VRUs, we end up at 2 Mbps.
Service Level Latency	**[ms]**	100 Recommended communication latency: 20	This is the maximum latency tolerable for a reaction due to moving VRUs very near the road. 20 ms for VRU communication latency are comparable to that of cooperative maneuvers and sensor sharing because we see that the VRU situations will occur much more unexpected and in close proximity to the vehicle. Thus, longer communication latencies would be adverse to the intended purpose. Justification: For a 50 km/hr drive in dense urban environments (80 m communication radius), the total time budget until a potential complete stop has to be initiated is approximately 3.96 s.
Service Level Reliability		99.9 %	High, the reliability here should be sufficient to guarantee QoS. 99.9 % should be sufficient, since additional vehicle sensors are in place that can help to avoid collisions.
Velocity	**[m/s]**	Urban: 22.22 Rural: 36.11	In urban areas, considering 80 km/h max. speed. In rural areas, considering 130 km/h max. speed.
Vehicle Density	**[vehicle/km^2]**	Concerned VRUs: ~300 total Present VRUs per km^2: ~10000 Vehicles: 1500	Figures given only for urban areas, since we consider this one as the more critical case with regards to vehicle number/density. Concerned VRUs are those near streets, not counting workers in offices or the like. However, for total network load, etc, all VRUs in the given area have to be considered.
Positioning Accuracy	**[m]**	< 0.5	In order to correct positioning based on GNSS (e.g. GPS, Galileo), this accuracy should be enhanced via the 3GPP System. The 3GPP System provides a positioning accuracy of < 0.5 m, e.g. considering support of GNSS, highly accurately positioned RSU and CV2X UEs.
Interoperability /Regulatory/	**[yes/no]**	Yes	In order to make it possible to share information and data on VRUs between vehicles, inter-OEM-operability should be guaranteed.

Standardisation Required			Interoperability of UEs with RSUs, vehicles, and other local entities should also be guaranteed. Sharing information collected by sensor data form vehicles passing/approaching the area where VRUs are present references UC T-170339.
Non-KPIs			
Power efficiency			The system should convey information from a VRU in a power efficient way. For example, it could be investigated if providing a power saving feature on the sidelink for handheld UEs is a solution. For instance, the eNB-aided form of discontinuous transmission/reception (DTX/DRX) that allows for power-saving in the UE should be considered by 3GPP System. Or perhaps enhancements on application or transport layer etc. are more appropriate.
VRU Trajectories			The 3GPP System should provide a network-enabled positioning service including history data of trajectories for VRUs.

6.2 Vehicle Operations Management

6.2.1 Software Update

Use Case Name	Software Update.
User Story	Vehicle manufacturer updates electronic control module software for targeted vehicles.
Category	Vehicle Operations Management.
Road Environment	Intersection | Urban | Rural | Highway | Other
Short Description	• Vehicle Manufacturer or Controlling Authority publishes software updates for one or more electronic control units (ECUs) on targeted host vehicles (HVs).
Actors	• Host vehicle (HV). • Vehicle manufacturer. • Controlling authority (could be fleet operator, owner / user onboard, etc.). • Human driver.
Vehicle Roles	• HV represents the targeted vehicle for an intended software update.
Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	• Vehicle manufacturer publishes software updates. • Vehicle controlling authority publishes software updates or approves installation of software update.

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

	• HV may download segments of the software update at opportune moments that do not affect the performance of safety features or other driver-facing features such as voice calls or streaming content, or to accommodate changing network availability. • HV may pause and continue downloads as needed; it should not re-start a large download from the beginning and may receive parts of the download out of order. Thus the download is "reliable" even given any gaps in coverage or delays caused by higher-priority uses of available bandwidth, or switching between multiple communications mechanisms. • When HV completes downloading the posted software update: a. HV should either retain a copy of the previously-installed version of software in case of an issue with the update that requires reverting to the previous version or having a mechanism to reverse the changes contained in the SW update package. b. HV receives approval from human driver (conventional, if required) or controlling authority (autonomous) to install the software update. Such a separate step after package download is not always mandatory. c. HV installs the downloaded software update at a safe, appropriate, driver-approved (where required) time. d. HV notifies vehicle manufacturer and controlling authority of update completion and an updated manifest of ECUs, installed software versions, retained rollback versions, any relevant download rate and installation statistics, etc. as appropriate for the SW update process.
Alternative Event Flow	• Vehicle manufacturer posts an optional software update and notifies targeted HVs of the new software version and features on affected ECUs. • HV owner is notified of the optional software update, its new features and cost if applicable. • If HV owner accepts or purchases the update: a. HV starts downloading the software update. b. HV may download segments of the software update at opportune moments that do not affect the performance of safety features or other driver-facing features such as voice calls or streaming content. c. HV may pause and continue downloads as needed; it should not re-start a large download from the beginning and may receive parts of the download out of order. Thus the download is "reliable" even given any gaps in coverage or delays caused by higher-priority uses of available bandwidth, or switching between multiple communications mechanisms. d. When HV completes downloading the posted software update: i. HV should either retain a copy of the previously-installed version of software in case of an issue with the update that requires reverting to the previous version, or else have a mechanism to reverse the changes contained in the new SW update package. ii. HV installs the downloaded software update at a safe, appropriate, driver-approved (where required) time. • HV notifies vehicle manufacturer and controlling party of update completion and an updated manifest of ECUs, installed software versions, retained rollback versions, any relevant download rate and installation statistics, etc. as appropriate for the SW update process.
Post-Conditions	• Mandatory software updates are deployed on target HVs. • Optional software updates are either rejected or deployed on target HVs.
Service-Level KPIs	• Download time. • Download size. • Reliability.

Information Requirements	• Urgency/criticality of update. • HV's list of ECUs with current software versions. • Vehicle manufacturers latest software versions per ECU on each HV. • Any dependencies between ECUs and software versions. • HV's software update download progress. • HV's software update installation progress.

User Story	Detailed description, specifics and main differences to the User Story in the main template
Software Update (Conventional-Routine)	The "normal" case requiring a software update in a conventional (non-autonomous) vehicle. Software download and software installation are separate. The software is downloaded securely and reliably, as coverage and bandwidth are available. Its transmission must not adversely affect any safety-critical or user experience-critical functions. The driver is asked for consent to install the software when appropriate. Software installation is a separate process that occurs when safe and convenient. It may also vary depending on the vehicle manufacturer, model, and specific ECUs. For example, a non-critical system might be updated any time but a safety-critical system might only be updated when the vehicle is securely parked and will not be used for an extended period.

Software Update (Conventional-Routine)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Within network service provider coverage	In principle, the User Story is applicable in the network service provider coverage area.
Information Requested/Generated	**Quality of information/ Information needs**	1.5GB within 168 hours	This is a current-day example of a major OEM update image that would be manually updated and installed today. Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications.
Service Level Latency	**[ms]**	Not applicable	Software updates themselves are not latency-sensitive.
Service Level Reliability	**[%]**	99 %	Software updates should reliably and successfully transfer but this can occur over an extended period, as above.

			Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range.
Velocity	**[m/s]**	22.22	Typical city speed (~80 km/h), where it will be helpful to collect software updates over time. Note that a consistent download rate is not required, since the download may collect parts of the software image as available and pause and continue downloading as needed.
Vehicle Density	**[vehicle/km^2]**	1500 < 15 vehicles/km^2 typically need a specific update at a time	Assuming an overall vehicle density of 1500 vehicles/km^2, but only a fraction of these would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. We expect that <1 % of vehicles would need a specific software update at any given time.
Positioning Accuracy	**[m]**	30	It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road. More precision could be helpful to validate that a vehicle is safely parked before an update installation begins, or whether it is within range of other communications mechanisms (e.g. home Wi-Fi).
Interoperability / Regulatory / Standardisation Required	**[yes/no]**	No/Yes/No	We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates, and this will not be interoperable across manufacturers. There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement. Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers.

User Story	Detailed description, specifics and main differences to the User Story in the main template
Software Update (Conventional-Urgent)	Urgent need for software update in a conventional (human-driven) vehicle. Driver is alerted to the need for an update. This could be similar to a “check engine” light or other alert. Unless otherwise mandated, the SW is downloaded automatically by the vehicle. Where required, the driver is asked for consent to install the software as soon as safe and appropriate. If consent is not required, the vehicle may choose to perform the installation when appropriate, and the driver may be notified before, during, and/or after. The software is downloaded securely and reliably, as coverage and bandwidth are available. Its transmission should not interrupt any safety-critical functions. Where required, the driver is asked for consent to install the software when appropriate. Software installation proceeds as in the case above.

Software Update (Conventional-Urgent)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Within network service provider coverage	In principle, the User Story is applicable in the network service provider coverage area.
Information Requested/Generated	**Quality of information/ Information needs**	1.5GB within 24 hours.	This is a current-day example of a major OEM update image that would be manually updated and installed today. Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications.
Service Level Latency	**[ms]**	1 hour to deliver “critical update required” message	The most stringent requirement is to deliver the “critical update required” message. The human driver is still responsible for safe vehicle operation. Software updates themselves are not latency-sensitive.
Service Level Reliability	**[%]**	99 %	Software updates should reliably and successfully transfer but this can occur over an extended period as above.

			Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range.
Velocity	**[m/s]**	22.22	Typical city speed (~80 km/h), where it will be helpful to collect software updates over time. Note that a consistent download rate is not required, since the download may collect parts of the software image as available and pause and continue downloading as needed.
Vehicle Density	**[vehicle/km^2]**	1500 < 15 vehicles/km^2 typically need a specific update at a time	Assuming an overall vehicle density of 1500 vehicles/km^2, but only a fraction of these would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. We expect that <1 % of vehicles would need a specific software update at any given time.
Positioning Accuracy	**[m]**	30	It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road. More precision could be helpful to validate that a vehicle is safely parked before an update installation begins or whether it is within range of other communications mechanisms (e.g. home Wi-Fi).
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	No/Yes/No	We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates and this will not be interoperable across manufacturers. There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement. Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers.

User Story	Detailed description, specifics and main differences to the User Story in the main template
Software Update (Autonomous-Routine)	The “normal” case requiring a software update in an autonomous (self-driving) vehicle. The controlling party is asked for consent to install the software, potentially specifying preconditions (e.g. no passengers aboard, during off-peak hours, during next refuelling/ recharging, etc.). The software is downloaded securely and reliably, as coverage and bandwidth are available. Its transmission must not adversely affect any safety-critical or user experience-critical functions. Software installation is a separate process that occurs when safe and the controlling party conditions are met.

Software Update (Autonomous-Routine)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Within network service provider coverage	In principle, the User Story is applicable in the network service provider coverage area.
Information Requested/Generated	**Quality of information/ Information needs**	3 GB within 24 hours	This is a conservative estimate of a current self-driving stack based on publicly-available information. Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications.
Service Level Latency	**[ms]**	Not applicable	Software updates themselves are not latency-sensitive.
Service Level Reliability	**[%]**	99 %	Software updates should successfully transfer reliably but this can occur over an extended period as above. Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range.
Velocity	**[m/s]**	22.22	Typical city speed (~80 km/h), where it will be helpful to collect software updates over time.

			Note that a consistent download rate is not required, since the download may collect parts of the software image as available and pause and continue downloading as needed.
Vehicle Density	**[vehicle/km^2]**	1500 < 15 vehicles/km^2 typically need a specific update at a time.	Assuming an overall vehicle density of 1500 vehicles/km^2, but only a fraction of these would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. We expect that <1 % of vehicles would need a specific software update at any given time.
Positioning Accuracy	**[m]**	30	It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road. More precision could be helpful to validate that a vehicle is safely parked before an update installation begins, or whether it is within range of other communications mechanisms (e.g. home Wi-Fi).
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	No/Yes/No	We expect individual vehicle manufacturers and 3rd party SW Update system developers will specify their own software updates and this will not be interoperable across manufacturers. There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement. However, the expectations for self-driving vehicles and corresponding regulations will require much greater urgency and may even include temporarily removing an affected vehicle from normal driving operations. Once the vehicle is parked, the urgency to apply the software update depends on commercial concerns such as the cost of vehicle downtime in an autonomous fleet. Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers.

User Story	Detailed description, specifics and main differences to the User Story in the main template
Software Update (Autonomous-Urgent)	Urgent need for critical software update in an autonomous (self-driving) vehicle. In this case, the first priority may be to **order the vehicle to safely exit the roadway and park**. The controlling party is informed of a critical need for an update and agrees to the vehicle state requirements to perform the download and update (e.g. en route or stopped, passengers on-board or empty, etc.). With controlling party's consent regarding the conditions, the vehicle update is performed, which may require steps to stop in a safe location and inform passengers on-board. Once the controlling party agrees to the conditions, the updates are downloaded to target vehicles, while necessary requirements for update installation (like safely parking) are addressed in parallel. If passengers are aboard, the controlling party (e.g. fleet operator) or vehicle informs passengers of the situation and attends to their comfort and safety. For example, another vehicle may be dispatched to carry the passengers to their destinations. Assuming no passengers are aboard or the download and installation can be completed with high confidence quickly (within minutes), the software download and installation proceed as in the routine case, but with a higher delivery priority (i.e. streaming or other content downloads take lower priority). In cases of longer update installation durations, passengers may be transferred to another vehicle and the download will occur as if routine while the vehicle is parked. However, the high cost of an expensive autonomous vehicle sitting idle while another is needed to deal with passengers, or any time the update can be accomplished more quickly than the arrival of a replacement vehicle, make the "update while you wait" scenario more compelling.

Software Update (Autonomous-Urgent)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Within network service provider coverage	In principle, the Use Case is applicable in the network service provider coverage area.
Information Requested/Generated	**Quality of information/ Information needs**	3 GB within 2 hours	This is a conservative estimate for a current self-driving stack based on publicly-available information. Normally, the process of downloading the software update occurs in the background and should defer to more latency-sensitive applications.
Service Level Latency	**[ms]**	10 minutes to deliver "critical	The most stringent requirement is to deliver the "critical update required" message, especially in

		update required" message	the case of an autonomous vehicle. But even this is in the range of minutes. Software updates themselves are not latency-sensitive.
Service Level Reliability	**[%]**	99 %	Software updates should reliably and successfully transfer but this can occur over an extended period, as above. Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when they are in range.
Velocity	**[m/s]**	70	This (250 km/h) is an allowed speed in some motorways and at least the "critical update required" message should be deliverable at any speed the vehicle is likely to travel. Ideally, the download itself can be completed at this speed. Once the vehicle is parked and secured, installation can be completed over a longer period.
Vehicle Density	**[vehicle/km^2]**	1500 vehicles/km^2 < 15 vehicles/km^2 typically need a specific update at a time.	Assuming an overall vehicle density of 1500 vehicles/km^2, but only a fraction of these would require a specific software update due to differing vehicle manufacturers, vehicle platforms, on-board equipment, and other factors. We expect that <1 % of vehicles would need a specific software update at any given time.
Positioning Accuracy	**[m]**	30	It is typically enough for the network service provider to identify in which street/road and approximate position inside this street/road. More precision could be helpful to validate that a vehicle is safely parked before an update installation begins or whether it is within range of other communications mechanisms (e.g. home Wi-Fi).
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	No/Yes/No	We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates and this will not be interoperable across manufacturers.

			There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement. However, the expectations for self-driving vehicles and corresponding regulations will require much greater urgency and may even include temporarily removing an affected vehicle from normal driving operations. Once the vehicle is parked, the urgency to apply the software update depends on commercial concerns such as the cost of vehicle downtime in an autonomous fleet. Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers.

User Story	**Detailed description, specifics and main differences to the User Story in the main template**
Software Update (Without Infrastructure)	Software update delivery outside network service provider coverage. A vehicle is outside of V2I/V2N coverage and enters the C-V2X range of another vehicle with the appropriate software update available. For example, two or more similar vehicles from the same managed fleet arrive in close proximity to transfer cargo, refuel/recharge, or for the explicit purpose of receiving an update or other maintenance. • Assumes a site outside network service or roadside infrastructure coverage where at least two vehicles come into close proximity of each other. • At least one vehicle (the "serving vehicle") holds the appropriate software update and can serve as a secure download server to the target vehicle(s). • Before the software transfer is initiated, the system in the serving vehicle identifies the target vehicle(s) and the need for software updates. This process may be done through a bulletin published by the serving vehicle which identifies vehicles needing specific updates. • The driver (human or robot) is informed that a critical update is in progress and that the vehicle should not be powered down or driven until update completion. • The download must happen over a short period while the vehicles are in close proximity of each other.

Software Update (Without Infrastructure)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**

Range	**[m]**	< 100 m between vehicles	This User Story assumes the vehicles are in close proximity.
Information Requested/Generated	**Quality of information/ Information needs**	1.5 GB	This is a current-day example of a major OEM update image that would be manually updated and installed today.
Service Level Latency	**[ms]**	30 seconds	The goal is to deliver updates vehicle-to-vehicle and minimise disruption to their regular activity.
Service Level Reliability	**[%]**	99 %	Software updates should successfully transfer completely and reliably 99 % of the time in the time desired above.
Velocity	**[m/s]**	0	We assume the vehicles will be parked in close proximity for this transfer.
Vehicle Density	**[vehicle/km^2]**	1500 vehicles/km^2 Minimum of 2 vehicles involved (server and target)	Assuming an overall vehicle density of 1500 vehicles/km^2, but this is a vehicle-to-vehicle application for a “peer to peer” transfer. Scenarios where one server delivers updates to multiple targets at a time are also desirable.
Positioning Accuracy	**[m]**	50	Vehicles need to be in close proximity, and are expected to identify each other directly.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	No/Yes/No	We expect individual vehicle manufacturers and third-party software update system developers will specify their own SW updates and this will not be interoperable across manufacturers. There may be regulatory requirements, and for conventional vehicles we rely on current expectations for updates, which typically require service by dealerships and may take months to schedule and implement. Standardisation could be helpful but is not required, given the proprietary nature of updates and specific architectural needs from different vehicle manufacturers.

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

Software Update (Vehicle to Workshop)	Software update delivery in a specific context, such as a dealership, workshop, or fleet parking facility. A vehicle enters an area where "private" C-V2X capability/RSU can quickly deliver a software update directly to the vehicle. For example, a vehicle enters a workshop for a brief service such as changing tyres or replacing fluids, and relevant software updates are available. The software is delivered quickly via a direct C-V2X connection while other services are performed. This reduces total downtime and provides updates in a safe situation where technicians are available in case of anomaly, taking advantage of close range and unlicensed spectrum. • Assumes a controlled environment such as a dealership/workshop, fuelling/ charging station, or fleet parking facility. • The download must be completed quickly with the car stationary, with systems powered on to handle the transfer and installation. • The driver (human or robot) and technician (if applicable) are informed that a critical update is in progress and that the vehicle should not be powered down or driven until update completion. • Before the software transfer is initiated, the secure local RSU identifies the target vehicle(s) and the need for software updates. This process may be done through a bulletin published by the RSU which identifies vehicles needing specific updates.

Software Update (Vehicle to Workshop)			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	< 100 m between vehicle and RSU	Scenario is within a specific location and context as described.
Information Requested/Generated	**Quality of information/ Information needs**	32 GB	This is a current-day example of a major OEM update package that today would be manually updated and installed.
Service Level Latency	**[ms]**	15 minutes	The goal is to deliver updates while other minor services such as tyre changes are performed.
Service Level Reliability	**[%]**	99.9 %	Software updates should successfully transfer reliably and within the desired timeframe.
Velocity	**[m/s]**	0 m/s	We assume the vehicles will be parked during the download.
Vehicle Density	**[vehicle/km^2]**	1500 vehicles/km^2 Up to 100 vehicles updated simultaneously	Assuming an overall vehicle density of 1500 vehicles/km^2, but a maximum of 100 vehicles to be updated at any one time within the facility.
Positioning Accuracy	**[m]**	50	Vehicles need to be in close proximity to the private C-V2X RSU.

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

6.2.2 Vehicle Health Monitoring

Use Case Name	Vehicle Health Monitoring.
User Story	Owners, fleet operators and authorised vehicle service providers monitor the health of HV and are alerted when maintenance or service is required.
Category	Vehicle Operations Management.
Road Environment	Intersection | Urban | Rural | Highway | Other

Short Description	• Owners, operators and vehicle service providers request a report of the HVs current health including:
	  ○ On-board diagnostic trouble codes
	  ○ Predicted maintenance (fluids, brakes, tyres, battery, etc.)
	• Owners, operators and vehicle service providers are alerted to new vehicle health issues requiring service and the vehicle's location when detecting:
	  ○ On-board diagnostic trouble codes
	  ○ Required maintenance (fluids, brakes, tyres, battery, etc.)

Actors	• Host vehicle (HV). • Vehicle owner. • Fleet operator. • Automotive service provider.
Vehicle Roles	HV represents the vehicle that needs maintenance or service.
Roadside Infrastructure Roles	Not applicable.
Application Server Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	• Provide owners, operators and vehicle service providers of HV health report on request. • Alert owners, operators and vehicle service providers of HV health issues requiring maintenance or service.
Needs	• Owners, operators and vehicle service providers need to know the health of the vehicle including:

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

User Story	**Detailed description and specifics**
User Story #1	A vehicle is travelling on a highway and is losing air pressure in one or more of its tyres. A road or fleet operator needs to be made aware of the situation.
User Story #2	
.....	

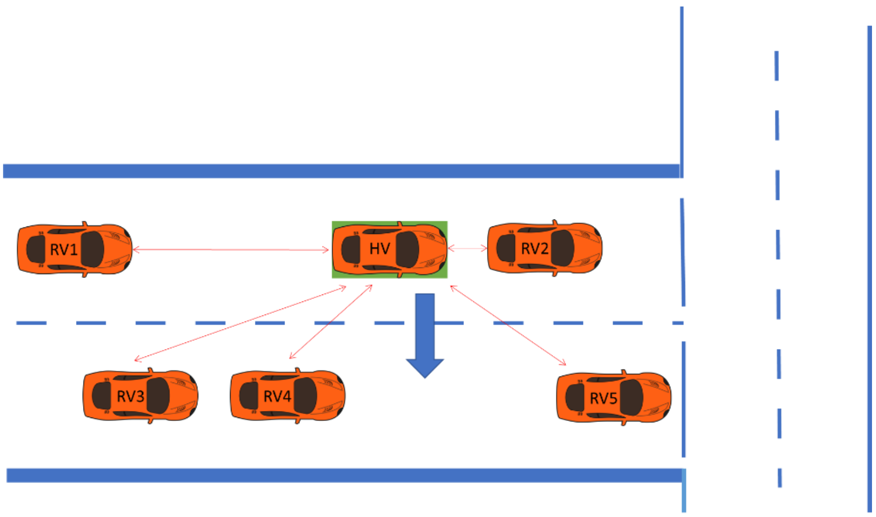
User Story #1			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**

Range	**[m]**	N/A	There is no concrete upper limit to the desired range. The vehicle needs to convey the message to the road operator or fleet manager cloud which in most cases is physically far away from the vehicle.
Information Requested/Generated	**Quality of information/ Information needs**	< 1 KB	The information must be timely and accurate. Since the information is safety related, it must be accurate.
Service Level Latency	**[ms]**	< 30 s	Latency is not a critical factor.
Service Level Reliability		99.99 %	It is critical that the information be sent and received successfully.
Velocity	**[m/s]**	44.4	Health monitoring related events and messages should be able to be sent successfully at highway driving speeds (example 160 km/h).
Vehicle Density	**[vehicle/km^2]**	4000 or max.	Vehicle that is on the verge of becoming stranded due to a degrading condition should be able to successfully send the information in a traffic congested environment.
Positioning Accuracy	**[m]**	1.5 m 3 σ (99.8%)	Since this information may be used to dispatch assistance, the location of the vehicle must be known within a lane width and within the vehicle's length. Here, 1.5 m is the typical accuracy required to locate a vehicle within a lane.
Interoperability/Regulatory/ Standardisation Required	**[yes/no]**	Yes	Information should be standardised to enable road operators to identify vehicles that are at risk of becoming stranded and dispatch an appropriate level of assistance.

6.3 Advanced Driving Assistance

6.3.1 High Definition Sensor Sharing

Use Case Name	High Definition Sensor Sharing.
User Story/Use Case scenario	The vehicle has automated driving mode and changes lanes.
Category	Convenience, Advanced driving assistance.
Road Environment	Suburban | urban | highway | rural.

Short Description	Vehicle uses its own sensors (e.g. HD camera, lidar), and sensor information from other vehicles, to perceive its environment (e.g. come up with 3D model of world around it) and safely performs an automated driving lane change.
Actors	• Host vehicles(HV). • Remote vehicles (RV).
Vehicle Roles	• On-board sensors detect other vehicles and objects. • On board processors calculate relative distances and trajectories of other vehicles. • Processed and/or un-processed information is shared with other vehicles.
Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	None.
Goal	Automated driving lane change safely performed.
Needs	• Capability of vehicle to calculate accurately, and in real time, its relative position with other vehicles, road markings and objects. • Capability of the vehicle to use its own sensor information and/or that of other vehicles, including those not in line of sight. • System must work during the day and the night, and in all weather conditions.
Constraints/ Presumptions	Not all vehicles will be equipped.
Geographic Scope	All.
Illustrations	 HV = Host vehicle RV = Remote vehicle
Pre-Conditions	• Necessary software available in clients and applications. • Communication means available. • The HV has to understand the sensor data from the RVs, in an agreed format.

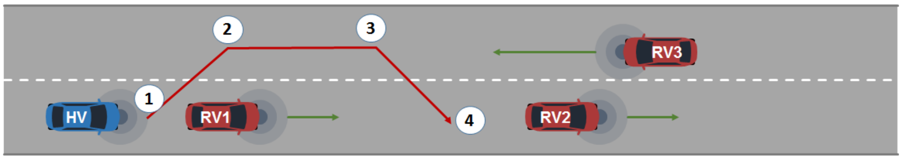
Main Event Flow	• HV captures 360 degree sensory information (e.g. other vehicles, road markings). • HV calculates in real time its distance from other vehicles and objects, their relative positions and their trajectories. • HV receives processed and/or un-processed information (e.g. video) from remote vehicles and uses that information to improve its perception of the surroundings and add certainty to its calculations. • HV, taking into account information received from RVs, calculates what the gap between RV4 and RV5 will be for the next n seconds. Host vehicle knows from information received from RV5 that a junction is near and therefore it is likely to slow down imminently. • HV determines that it is safe to move from the left lane to the right lane. • HV notifies remote vehicles of its intention. • HV performs the manoeuvre, adjusting its speed to the optimum.
Alternative Event Flow	As above except in step 3 the HV requests sensor information from specific RVs.
Post-Conditions	The vehicle has moved from the left lane to the right lane.
Service Level Requirements	See table below.
Information Requirements	• Accurate dynamic relative position and planned trajectory • High-definition images. • LIDAR. • Dynamic 3D absolute position. • Accuracy of the data and liability for sharing. • Agreed formats of data for sharing.

Lane change on automated driving mode			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	Min. 80	40 m is approximately 2 s driving time at 160 km/h, which should provide enough time for sensor sharing negotiation.
Information Requested/Generated	**Quality of information/ Information needs**	Numerical	Processed and unprocessed data may be exchanged. Near zero error rate tolerance (after error correction) on transmission link is required. Max. 1000 bytes packet size (processed data). Larger for un-processed data.
Service Level Latency	**[ms]**	10	Lowest possible latency is needed to reduce reaction times of HV and RV. 10 ms is considered realistically achievable in Rel-16.

Service Level Reliability		99.9 %	Very high, the reliability here should be sufficient to guarantee QoS (whole system).
Velocity	**[m/s]**	44.4	Max. highway speed assumed to be 160 km/h.
Vehicle Density	**[vehicle/km^2]**	4000	Max. assumed density in urban situation.
Positioning Accuracy	**[m]**	0.1 m	Relative between two vehicles. High accuracy is required to avoid collision.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation. Processed sensor data shall be understandable between different manufactures' implementations.

6.3.2 See-Through for Passing

Use Case Name	See-Through for Passing.
User Story	Driver of host vehicle (HV) that signals an intention to pass a remote vehicle (RV) using the oncoming traffic lane is provided a video stream showing the view in front of the RV.
Category	Convenience | Advanced driving assistance.
Road Environment	Rural two-lane highways.
Short Description	• HV approaches from behind or follows RV1 with the intention to pass using the oncoming lane. • Video stream of the front view of RV1 is shown to the HV driver during the passing manoeuvre.
Actors	• Host vehicle (HV). • Remote vehicle 1 (RV1). • Remote vehicle 2 (RV2). • Remote vehicle 3 (RV3).
Vehicle Roles	• HV represents the vehicle intending to pass RV1. • RV1 represents the vehicle being passed. • RV2 represents the vehicle in front of RV1. • RV3 represents the closest vehicle in the oncoming traffic lane.
Roadside Infrastructure Roles	• Roads must define their lanes and direction of traffic flow in each lane. • Road must indicate where passing is not permitted across traffic lanes.
Application Server Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	Provide HV driver a clear, reliable and real-time view of the road situation in front of the vehicle it is trying to pass and help avoid possible collision.

Needs	• Communication capabilities allowing real-time video transfer. • High-resolution display in HV.
Constraints / Presumptions	• HV and RV meet basic communications capabilities and performance requirements described for sending and receiving messages. • HV and RV are equipped to send and receive messages as well as high-bandwidth real-time video content.
Geographic Scope	National.
Illustrations	 • State 1 = HV starts receiving streaming video from RV1 • State 2 = HV has fully moved into the passing lane, continues receving video streaming from RV1 • State 3 = HV has reached the position in the passing lane when it is ready to start the manoeuvre to return to the starting lane • State 4 = HV completes the passing maneuver and can stop receiving the streaming video from RV1
Pre-Conditions	• HV is approaching from behind or following RV1. • The HV and RV are in communication range. • The RV is capable of collecting front facing visual information.
Trigger	• HV signals its intention to pass RV1. • HV driver requests visual of the RV1's front view.
Main Event Flow	• The HV is approaching the RV from behind in the same lane. • HV is following RV on a two-way road and makes a decision to initiate a passing manoeuvre. • HV requests RV's visual information from its front view for the purpose of making a passing decision as well as additional information during the passing manoeuvre. • The RV provides visual information from its front view periodically or event-based. • The HV receives the visual information from the RV. • The HV driver is able to see the RV front facing.
Alternative Event Flow	None.
Post-Conditions	Based upon the visual information from the RV, the HV driver is able to: • Make an informed decision to overtake the RV when there is no traffic coming in on the opposite direction. • Complete a successful passing manoeuvre with the additional visual information from RV1.
Service Level KPIs	• Velocity. • Data rate. • Range. • Latency.

	• Video quality.
Information Requirements	• Video streaming capability between vehicles as well as short message exchange capability.

The following table provides the specific requirements for the above User Story.

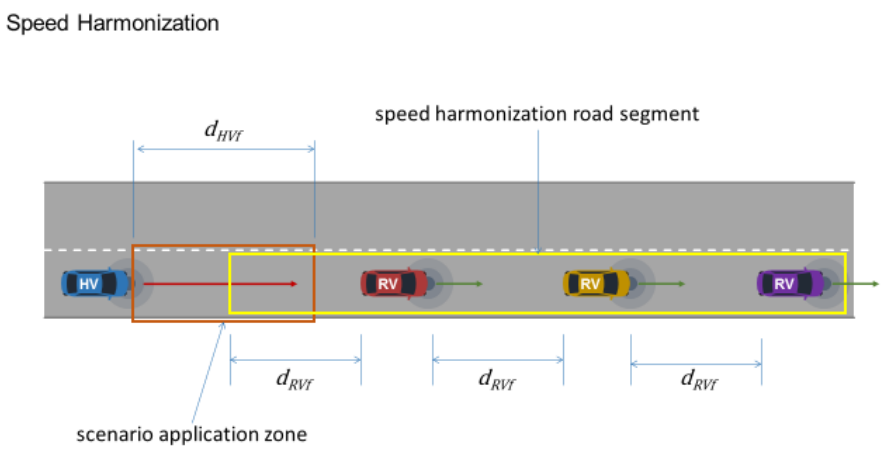
See-Through for Passing			
SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	100	As the two vehicles concerned in the exchange of visual information are driving in the same lane, the communication range is from 50-100 m, considering a legal headway of 2 s.
Information Requested/Generated	**Quality of information/ Information needs**	15 Mbps	Video streaming. 15 Mbps are needed to transmit a progressive high-definition video signal with resolution 1280x720, frame rate 30 Hz, colour depth 8 bit, 24 bit resolution, subsampling 4:2:2 and a typical compression of 1:30 (e.g. with H.264).
Service Level Latency	**[ms]**	50 ms	The latency requirement for a video frame depends on the vehicle speed and heading as well as pitch angle changes. Latency of 50 ms should be kept, lower values would increase the experience of this function. Additional delays would lead to additional buffering in the rear vehicle. 50 ms is the considered e2e communication layer latency, without including application layer processing times e.g. coding, de-coding. Additional latency requirements: • The duration of service discovery phase should be in maximum 500 ms (i.e. time duration for HV to identify if RV supports the see-through service). Service discovery includes the communication establishment phase (i.e. receive resources) as well as the discovery request and discovery response messages that HV and RV send, respectively. • The see-through establishment phase (i.e. a) HV asks for see-through and b) RV provides the first video frame) should complete within maximum within 500 ms. • Service discovery and see-through establishment within 1000 ms will help the driver of the HV to activate the requested see-through service quickly

			and take a fast decision whether to proceed within the overtake action. This also affects the engagement of the driver with the see-through application. • The see-through release phase should be complete within maximum 500 ms.
Service Level Reliability		99 %	Reliability of 99 % at the communication layer for video frames is needed to avoid massive artefacts that may lead to degradation of video quality for assisted driving. The video will be used to distinguish objects, front vehicles etc. in order to support a driver's decision to overtake or not.
Velocity	**[m/s]**	33.33	This is the maximum speed limit for non-urban streets (i.e. not highways).While 120 kmph is the maximum speed of the HV and RV. Note: The transmitter of the video and the vehicle receiving the information will be more or less at the same speed 0-30 km/h (relative velocity).
Vehicle Density	**[vehicle/km^2]**	1500	This type of service is most likely to be used in rural road environments. Two vehicles are involved in this Use Case.
Positioning Accuracy	**[m]**	1.5 m (99.8 %)	Positioning accuracy to know HV's and RV's location (including direction) and lane.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Interoperability: Yes Regulation: Yes Standardisation: Yes	Interoperability is needed between the vehicles that participate in the see-through service. Regulatory oversight for safety-related issues is needed. Standardisation on the application layer (message set and flow control).

6.4 Traffic Efficiency

6.4.1 Speed Harmonisation

Use Case Name	Speed Harmonisation.
User Story	Notify HV of recommended speed to optimise traffic flow, minimise emissions and to ensure a smooth ride.

Category	Traffic efficiency.
Road Environment	Urban | Rural | Highway
Short Description	Notify HV of recommended speed based on traffic, road conditions and weather information.
Actors	Host vehicle (HV).
Vehicle Roles	HV represents the vehicle receiving posted speed limits.
Road and Roadside Infrastructure Roles	• Roads are defined by their lane designations and geometry. • Posted speed limits are associated with road and lane segments.
Other Actors' Roles	Not applicable.
Goal	• Notify HV of the optimal speed to enable a comfortable ride and alleviate the need for frequent acceleration and deceleration. • Promote environmentally-friendly driving patterns. • Reduce risks of collisions due to stop and go traffic.
Needs	HV needs to know the recommended speed to optimise traffic flow, minimise emissions and to ensure a smooth ride.
Constraints/ Presumptions	RVs on the harmonised road segment are aware of the recommended speed.
Geographic Scope	Global.
Illustrations	 d_{HVf} = safe following distance of HV d_{RVf} = safe following distance of RV

Pre-Conditions	• HV is moving forward.
	• The scenario application zone is determined from:
	    ○ HV's location and dynamics
	    ○ HV's safe following distance
	    ○ lane designations and geometry
	    ○ posted speed limits
	• The speed harmonisation road segment is determined from:
	    ○ RVs' location and dynamics
	    ○ RVs' safe following distance
	    ○ Lane designations and geometry
	    ○ Road conditions (if available)

Main Event Flow	• If the "speed harmonisation road segment" is in the scenario application zone: ○ Notify HV of the recommended harmonised speed
Post-Conditions	• HV is aware of the recommended harmonised speed.
Service Level Key Performance Indicators	• Positioning accuracy. • Information age. • Communications range.
Information Requirements	• HV's location and dynamics. • HV's safe following distance. • RVs' location and dynamics. • RVs' safe following distance. • Lane designations and geometry. • Posted speed limit associated with lane or road segments. • Road conditions (if available).

User Story #1

In User Story#1, we assume human driver drives HV which would then result in taking human reaction time into account for SLR calculation.

SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	123/59/26	This value is calculated as a concatenation of the braking distance of HV and d_{RVf}. d_{RVf}. It can be derived from the typical braking distance formula with the velocity of stationary vehicles (i.e. RV). Braking distance formula = *(Human reaction time)*velocity + velocity^2/(2μg)* where μ represents the coefficient of friction and g represents gravitational acceleration. In order to acquire sample values, we used the following assumptions $\mu = 0.8$ $g = 9.8$ [m/s^2] *Human reaction time = 1.0 [s].*
Information Requested/Generated	**Quality of information/ Information needs**	Information about RV(s) speed/ position Information to HV about	Information may be processed locally by HV to determine harmonised speed (if only dependent on RV(s) speed/position). Information may be processed by external entity that determines recommended speed to advise HV.

		recommended speed (Max. 300 bytes for payload size)	Assuming 300 bytes is enough to carry speed and location information.
Service Level Latency	**[ms]**	2500/1800/1400	Latency should be low enough to allow a smooth adjustment, collisions could be prevented by on-board sensors or other means. Exact value can be derived from d_{RVf} divided by speed gap between HV and RV.
Service Level Reliability	**[%]**	80 %	This should be relatively lower than the value for other safety critical Use Cases.
Velocity	**[m/s]**	Highway: 50 Rural: 28 City: 14	Assuming typical maximum allowed speeds and some safety margin.
Vehicle Density	**[vehicle/km^2]**	10,000	Max. assumed density in urban situation.
Positioning Accuracy	**[m]**	1.5 m	Same as other scenario which requires lane level positioning accuracy, assuming different speed limit is applicable per lane.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

User Story #2

In User Story#2, we assume HV is highly automated, therefore human reaction time does not have to be considered at all.

SLR Title	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	**[m]**	59/23/8	This value is calculated as concatenation of braking distance of HV and d_{RVf}. d_{RVf} can be derived by typical braking distance formula with velocity of stationary vehicle(i.e. RV). Braking distance formula = *(Human reaction time)*velocity + velocity^2/(2μg)* where *μ* represents coefficient of friction and *g* does gravitational acceleration. In order to acquire sample values, we used following. *μ = 0.8*

			g = 9.8 [m/s^2] *Human reaction time = 0 [s]*
Information Requested/Generated	**Quality of information/ Information needs**	Information about RV(s) speed/position Information to HV about recommended speed (Max. 300 bytes for payload size)	Information may be processed locally by HV to determine harmonised speed (if only dependent on RV(s) speed/position). Information may be processed by external entity that determines recommended speed to advise HV about. Assuming 300 bytes is enough to carry speed and location information.
Service Level Latency	**[ms]**	1500/800/400	Latency should be low enough to allow a smooth adjustment, collisions could be prevented by on-board sensors or other means. The exact value can be derived from d_{RVf} divided by the speed gap between HV and RV.
Service Level Reliability	**[%]**	80 %	This should be relatively lower than the value for other safety critical Use Cases.
Velocity	**[m/s]**	Highway: 50 Rural: 28 City: 14	Assuming typical maximum allowed speeds and some safety margin.
Vehicle Density	**[vehicle/km^2]**	10,000	Max. assumed density in urban situation.
Positioning Accuracy	**[m]**	1.5 m	Same as other scenarios which require lane level positioning accuracy, assuming different speed limits are applicable per lane.
Interoperability /Regulatory/ Standardisation Required	**[yes/no]**	Yes	Interoperability between manufacturers' implementations to be guaranteed by standardisation.

7 Conclusions

This document provides the latest descriptions, User Stories, and Service Level Requirements for the first set of Use Cases (also referred to as Volume I, previously WAVE1 Use Cases) as part of the 5GAA WG1 work item "Use Case and KPI Requirements" [3]. The Use Cases originate from the 5GAA Board Internal Guidance Document [1].

The initial Use Case discussion in 5GAA WG1 showed diverse understanding of the same Use Case. Consequently, the need for a framework to describe Use Cases was identified. Furthermore, between the WGs in 5GAA it was agreed that WG1 should focus on solution-agnostic Use Case descriptions and requirements development. In line with this evolutionary mission definition, WG1 went through several iterations to develop a framework for Use Case descriptions, User Stories, and corresponding Service Level Requirements. Alongside the iterations, the framework was (re)applied to selected Use Cases. In its current version, the framework will be used and applied to further Use Cases.

5GAA Automotive Association

APPENDIX C

C-V2X Use Cases and Service Level Requirements Volume II

5GAA Automotive Association
Technical Report

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Contents

Foreword

This Technical Report has been produced by 5GAA.

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

x-nnzzzz

(1) This numbering system has six logical elements:

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

where x =

T (Use Cases and Technical Requirements)

A (System Architecture and Solution Development)

P (Evaluation, Testbed and Pilots)

S (Standards and Spectrum)

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

(b) nn: two digits to indicate the year. i.e. 16,17,18, etc

(c) zzzz: unique number of the document

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

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

1 Scope

The present report contains the second volume (Volume II) of 5GAA WG1 agreed Use Case (UC) descriptions for '5G Use Cases' developed within the 5GAA WG1 work item 'Use Case and KPI requirements' [1]. This second volume was previously named Wave 2.

The results and conclusions of this report, and of the future Use Case descriptions and related communication requirements are intended to serve as input for the work of other WGs in 5GAA, as well as sources for input and feedback to standardisation activities, e.g. in 3GPP.

2 References

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

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

[1] 5GAA T-180065, 'Work Item Description: Use Case and Service Level requirements', Munich, Germany, February 2018

[2] 5GAA T-200100, 'TR_C-V2X_Use_Cases_and_Service_Level_Requirements_Vol_I_V3.0_draft03', 2020

[3] 5GAA T-200023, 'Cooperative Traffic Gap', 2020

[4] 5GAA T-190133, 'Interactive VRU Crossing (NRV2X UC)', 2019

[5] 5GAA T-190060, 'Use Case Description: Software Update of Reconfigurable Radio', Intel, 2 April 2019

[6] 5GAA T-190139, 'Automated Valet Parking: Proof of Authentication and Localisation', 2019

[7] 5GAA T-190073, 'Use Case Description: Automated Valet Parking (Wake Up)', Audi, BMW, 30 January 2019

[8] 5GAA T-190037, 'Use Case Description: Awareness Confirmation', Audi, VW, BMW, 30 January 2019

[9] 5GAA T-190132 , 'Cooperative Curbside Management', 2019

[10] 5GAA T-190134 'Cooperative Lateral Parking', 2019

[11] 5GAA T-180146, 'Use Case Description: In-Vehicle Entertainment (IVE) – High Definition Content Delivery, On-line Gaming and Virtual Reality', July 2018

[12] 5GAA T-180248, 'Use Case Description: Obstructed View Assist', December 2018

[13] 5GAA T-190136, 'Vehicle Decision Assist', 2019

[14] 5GAA T-180115, 'Use Case Description: Automated Intersection crossing', 2018

[15] 5GAA T-180257, 'Use Case Description: Autonomous Vehicle Disengagement Report', Ford, 30 January 2019

[16] 5GAA T-190032, 'Cooperative Lane Merge', 2019

[17] 5GAA T-180193, 'Use Case Description: Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations', 2018

[18] 5GAA T-190068, 'Use Case Description: Coordinated, Cooperative Driving Manoeuvre', BMW, 23 April 2019

[19] 5GAA T-180250, 'Use Case Description: High definition map collecting & sharing', December 2018

[20] 5GAA T-190061, 'Use Case Description: Infrastructure Assisted Environment Perception', Intel, 2 April 2019

[21] 5GAA T-190062, 'Use Case Description: Infrastructure based Tele-Operated Driving', Intel, 2 April 2019

[22] 5GAA T-180155, 'Use Case Description: Remote Automated Driving Cancellation (RADC)', July 2018

[23] 5GAA T-180205, 'Use Case description: Tele-Operated Driving', June 2018

[24] 5GAA T-180206, 'Use Case description: Tele-Operated Driving Support', June 2018

[25] 5GAA T-180207, 'Use Case description: Tele-Operated Driving for Automated Parking', June 2018

[26] 5GAA T-190034, 'Use Case Description: Vehicle Collects Hazard and Road Event for AV', China Mobile, Continental, 30 January 2019

[27] 5GAA T-190035, 'Use Case Description: Vehicles Platooning in Steady State', Huawei, Nokia, Qualcomm, Denso, 30 January 2019

[28] 5GAA T-190155 'Bus Lane Sharing Request', 2019

[29] 5GAA T-190143, 'Bus Lane Sharing Revocation', 2019

[30] 5GAA T-180231, 'Use Case description: Continuous Traffic Flow via Green Lights Coordination', October 2018

[31] 5GAA T-180152, 'Use Case description: Group Start', June 2018

[32] 5GAA T-180260, 'Use Case Description: Accident Report', Ford, 30 January 2019

[33] 5GAA T-190005, 'Use Case Description: Patient Transport Monitoring', Ford, 30 January 2019

3 Definitions, Symbols and Abbreviations

3.1 Definitions

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

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

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

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

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

3.2 Abbreviations

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

SLR	Service Level Requirement
UC	Use Case
KPI	Key Performance Indicator
HV	Host Vehicle
RV	Remote Vehicle
VRU	Vulnerable Road User
OEM	Original Equipment Manufacturer
TTC	Time-to-Collision
VR	Virtual Reality
QoS	Quality of Service
QoE	Quality of Experience
PTV	Patient Transport Vehicle

4 Introduction

Following the first volume (Volume I) set of Use Case descriptions (previously named as 'WAVE 1') and the corresponding framework developed in WG1, this document presents the second volume of Use Case descriptions (previously named as 'WAVE 2'). One of the goals with this second set is to describe advanced Use Cases that have challenging requirements for future communication systems, such as 5G – as reflected in the report title.

The Use Case descriptions are written from the vehicle perspective and strive to be solution agnostic and applicable to both driven and autonomous vehicles. The realisation of Use Cases does not preclude applications performing various tasks supporting the Use Cases, such as collecting information, analysing etc. Furthermore, radio symbols in figures indicate a connected vehicle. The templates for Use Case descriptions, the Use Case classification scheme and in general the methodology that WG1 has developed for the description of the Use Cases and the corresponding Service Level Requirement (SLRs) are presented in [2].

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

The original Use Case descriptions were developed in separate documents as listed below. This document presents consolidated SLRs, refining the previously derived SLRs. Note that this means that some of the values in the original descriptions referred to below are outdated.

- Cooperative Traffic Gap [3]
- Interactive VRU Crossing [4]
- Software Update of Reconfigurable Radio System [4]
- Automated Valet Parking – Joint Authentication and Proof of Localisation [6]
- Automated Valet Parking (Wake Up) [7]
- Awareness Confirmation [8]
- Cooperative Curbside Management [9]
- Cooperative Lateral Parking [10]
- In-Vehicle Entertainment (IVE) – High-Definition Content Delivery, On-line Gaming and Virtual Reality [11]
- Obstructed View Assist [12]
- Vehicle Decision Assist [13]
- Automated Intersection Crossing [14]
- Autonomous Vehicle Disengagement Report [15]
- Cooperative Lane Merge [17]
- Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations [18]
- Coordinated, Cooperative Driving Manoeuvre [19]
- High-Definition Map Collecting and Sharing [20]
- Infrastructure Assisted Environment Perception [21]
- Infrastructure-Based Tele-Operated Driving [22]
- Remote Automated Driving Cancellation (RADC) [23]
- Tele-Operated Driving [24]
- Tele-Operated Driving Support [25]
- Tele-Operated Driving for Automated Parking [25]
- Vehicles Collects Hazard and Road Event for AV [26]
- Vehicles Platooning in Steady State [27]
- Bus Lane Sharing Request [28]
- Bus Lane Sharing Revocation [29]
- Continuous Traffic Flow via Green Lights Coordination [32]
- Group Start [32]
- Accident Report [32]
- Patient Transport Monitoring [33]

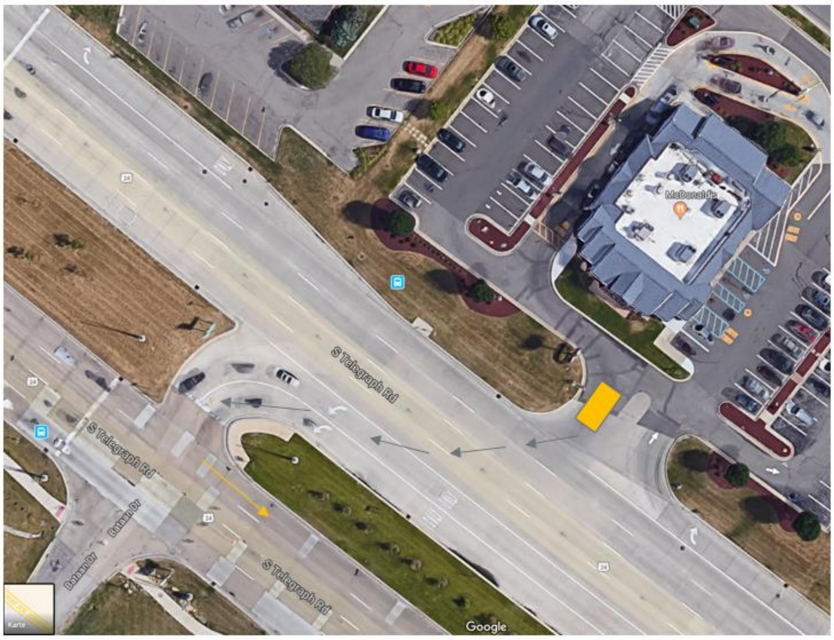
The remainder of this document is structured as follows. Section 5 contains the Use Case descriptions and the SLRs. Section 6 concludes the document.

5 5G C-V2X Use Cases Descriptions

5.1 Safety

5.1.1 Cooperative Traffic Gap

Use Case Name	**Cooperative Traffic Gap**
User Story #1	The host vehicle is about to make a manoeuvre which involves multiple space-time boxes (e.g. multiple lanes which have to be crossed). Most prominent examples are vehicles merging into a certain lane of a multi-lane road or a commercial truck making a U-turn. The vehicle, which can be automatically or manually driven, sends out a request to all vehicles in the traffic flow. • Due to the limited capabilities of the host vehicle (HV) doing this, the vehicles in the traffic flow will cooperate to find if there is sufficient vehicles among them equipped and willing to cooperate by freeing up the space requested by the vehicle. This is a topic involving multiple Use Cases with complex interactions. • If there are sufficient vehicles available, communication with the host vehicle will be started, to inform it about the upcoming traffic gap along with an estimated time. • The HV can, for example, pre-train its sensors or provide timing information to the driver requesting a 'cooperative gap', which is the space-time box the host vehicle uses and the remote vehicles then keep free. • The remote vehicles (RV) confirm their awareness of the usage of the space-time boxes in the gap by the HV. • The HV starts to execute its manoeuvre, while potentially informing others about the execution status. • Each RV checks if the host vehicle has passed through the space-time boxes in which the RV controls the traffic behind it. If it is the case, the RV takes no further part in the cooperative interaction, as it has no concrete contributions for the on-going manoeuvre. If not, the RV waits until the host vehicle passes through the lane where the RV is located. When the host vehicle receives a request to leave the cooperative interaction from an remote vehicle, it checks if it has passed the corresponding lane. If it has, it acknowledges the request.
Category	Convenience, safety.
Road Environment	Urban.
Short Description	• A vehicle tries to pull into a certain lane of a multi-lane road. To do so, it needs to cross multiple lanes. • It asks vehicles in the traffic flow to cooperate in forming a gap to support the host vehicle's manoeuvre.

	If enough vehicles are (opportunistically) found to support this, the host vehicle is informed by the supporting group.
Actors	Vehicle.
Vehicle Roles	Host vehicle and remote vehicles.
Road/Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	Improve safety and convenience in a multi-lane driving manoeuvre.
Needs	Remote vehicles need to cooperate.
Constraints/ Presumptions	The manoeuvre needs to be called off if one of the vehicles/drivers decides it will no longer support the manoeuvre. The manoeuvre can only be called off if the host vehicle has not started any activity yet. If the host vehicle has started, a cooperative manoeuvre alignment is required to solve the situation.
Geographic Scope	Anywhere.
Illustrations	 The vehicle indicated by the orange box tries to merge onto the multi-lane road and go to the leftmost lane as it wishes to turn.
Pre-Conditions HV	Host vehicle is ready to start a manoeuvre, but needs to wait for a traffic gap to open up in an ongoing traffic flow.
Pre-Conditions RVs	All participating remote vehicles are in the traffic flow for which the host vehicle is expecting a gap to open up.
Main Event Flow	• Host vehicle sends information that it would like others to form a traffic gap. • Receiving vehicles cooperate among each other to find out if there is sufficient and advantageously positioned vehicles to support the

	request by the host vehicle. This is a complex interaction requiring an efficient protocol. • Assuming there is not sufficient supporters, the host vehicle receives no reply. • Assuming there is sufficient supporters, potentially a subset of the supporting vehicles will communicate with the host vehicle about the upcoming gap, its estimated size, and when the gap will become visible and usable to the host vehicle. If there is multiple gap offers from the supporters, the host vehicle will choose one and acknowledge to its communication partner from the group of supporting vehicles.
Alternative Event Flow	Not applicable.
Post-Conditions	None.
Information Requirements	Car sensor data.

5.1.2 Interactive VRU Crossing

Use Case Name	**Interactive VRU Crossing**
User story #1	A vulnerable road user (e.g. pedestrian, cyclist) expresses intent to cross a road. Vehicles approaching the area in which the VRU intends to cross receive the message and send an acknowledgment when they have begun to slow down to allow the VRU to cross safely. Upon receiving this acknowledgment from the vehicles, the VRU may cross the street. Upon reaching the other side of the street, the VRU may send another message to the vehicles confirming that he/she has safely crossed.
Category	VRU safety.
Road Environment	Urban.
Short Description	• A VRU is preparing to cross the street. • After signalling this intent, nearby vehicles send an acknowledgement to reassure the VRU that it is safe to cross. • As the VRU is crossing, communicating continues with stopped vehicles o The VRU tells vehicles when it has cleared the zone in front of them so that they may continue driving. The VRU double checks with vehicles just before moving in front of them that they are clear to move forward.
Actors	Vehicle(s), vulnerable road user.
Vehicle Roles	Vulnerable road user and remote vehicles.
Road/Roadside Infrastructure Roles	Not applicable.

Other Actors' Roles	Not applicable.
Goal	Improved safety for VRUs and awareness for vehicles.
Needs	Not applicable.
Constraints/ Presumptions	Not applicable.
Geographic Scope	Non-highway roads with pedestrian traffic.
Illustrations	Not applicable.
Pre-Conditions HV	Not applicable.
Pre-Conditions RVs	Not applicable.
Main Event Flow	• VRU approaches street. • VRU expresses intent to cross. • Approaching vehicle receives message and performs target classification. • If the vehicle determines that it can accommodate the request, it acknowledges the VRU and notifies nearby vehicles that it is stopping. • When the VRU receives sufficient evidence that it is safe to cross (may vary with number of lanes and vehicles present), crossing is initiated. • While the VRU is crossing, his/her personal device sends information (e.g. PSMs) notifying stopped vehicles of its progress. When vehicles are safe to proceed after the VRU crosses, they begin moving again.
Alternative Event Flow	After a vehicle has sent an acknowledgment, if they begin accelerating early again, a NACK should be sent to the pedestrian, cancelling the positive indication they previously received.
Post-Conditions	The VRU may send a session-closing message to vehicles notifying them of successful crossing.
Information Requirements	• Accurate positioning. • VRU ID. • Local map data (to determine how many vehicles need to stop, i.e. how many lanes are there).

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	500	Message does not need an extreme range, as it only needs to reach nearby vehicles that should stop for a pedestrian. However, vehicles on high-speed roads will need adequate time to stop.

Information Requested/Generated	Quality of information/Information needs	64 Kbps	Pedestrian must send a 'heartbeat' message (including location data e.g. PSM) after a small 'request' message; the vehicle only needs to send acknowledgment.
Service Level Latency	[ms]	100	Exchange of messages must happen quickly, but a manoeuvre will only be initiated upon agreement, so slow messaging is not necessarily a safety risk.
Service Level Reliability	%	99.9	Again, since a manoeuvre will only be initiated upon agreement, dropped messages will not result in an immediate and significant safety risk.
Velocity	[m/s]	19.4 m/s	Upper end of the speed that a vehicle will be driving at on a road with a pedestrian crossing (70 km/h).
Vehicle Density	[vehicle/km^2]	730	Assumes vehicles within 500 m radius of roads with 2 lanes of traffic in each direction.
Positioning	[m]	0.2 (3σ)	If a pedestrian is standing next to a roadway, it only takes a slight position error to place them in the middle of the street on a map, or directly in the trajectory of a vehicle. Alternatively, if the pedestrian is crossing, a small error could falsely indicate to a nearby vehicle that the pedestrian is on the sidewalk.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability due to different OEMs and mobile device manufacturers. Regulation is needed to determine when a vehicle must meet a VRUs intent to cross, and when they may not. A standardised protocol is needed.

5.2 Vehicle Operations Management

5.2.1 Software Update of Reconfigurable Radio System

Use Case Name	**Software Update of Reconfigurable Radio System**

User Story	The HV's reconfigurable radio system has its software or firmware updated with a new feature set, or new standard release, to comply with regional requirements, etc.
Category	Vehicle operations management.
Road Environment	Intersection, urban, rural, highway, other.
Short Description	• Vehicle OEM, equipment manufacturer or chipset vendor publishes software or firmware updates for one or more reconfigurable radio systems on targeted HVs. • Or HV enters a geographic region with specific regulatory radio requirements and its equipment needs to be adjusted accordingly. • Or a driver or passenger requests to install a feature or standard due to specific needs in a specific location. • Updates can serve to increase radio feature sets, due to new releases of wireless communications standards or to comply with a specific (regional) regulation not available in the installed radio software version. Updates can also mitigate vulnerabilities and implementation issues that were discovered after market deployment.
Actors	• Host vehicle. • Vehicle OEM, equipment manufacturer or chipset vendor. • Driver or passenger.
Vehicle Roles	HV represents the targeted vehicle for an intended reconfigurable radio software or firmware update.
Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	• Vehicle OEM, equipment manufacturer or chipset vendor publishes radio software or firmware updates or is requested by driver or passenger • The driver or passenger requests vehicle OEM, equipment manufacturer or chipset vendor to provide a specific radio software or firmware version. An automated system in the HV passenger requests OEM, equipment manufacturer or chipset vendor to provide a specific radio software or firmware version.
Goal	Deliver radio software or firmware updates targeted at HVs upon request from the vehicle OEM, equipment manufacturer, chipset vendor, driver, passenger or automated system in HV.
Needs	Driver and passengers in the HV need to be provided with reliable and high-quality connectivity.
Constraints/ Presumptions	• Vehicle OEM, equipment manufacturer or chipset vendor targets an update for a list of vehicles. • A software update may depend on a chain of previous versions. • A radio software update may be mandatory or optional.

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- A radio software update might be rolled back.
- HVs will retain one previous radio software version to facilitate rollbacks.
- Downloading radio software updates should not affect the performance of safety features.

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<tr><td>Geographic Scope</td><td>Global, national or regional.</td></tr>
<tr><td>Illustrations</td><td>

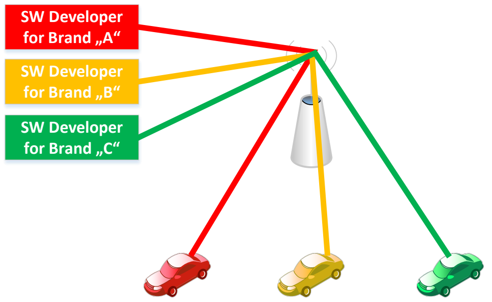

Figure 1: First generation – each vehicle type receives dedicated software (SW) package (platform specific executable code)

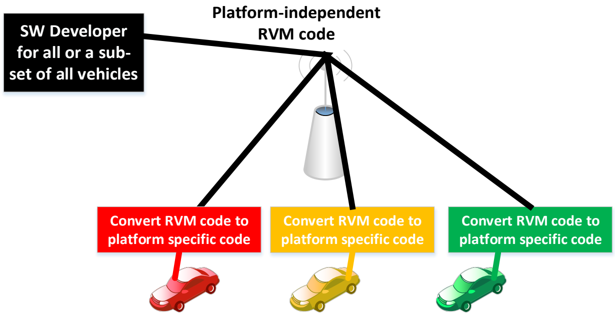

Figure 2: Second generation – each vehicle type (of a predefined set of vehicles) receives identical, platform-independent SW package and converts it to platform specific code

It should be noted that this UC may apply to various types of reconfigurable radio systems, including

i)Software-defined radios (full reconfigurability)
ii) ASIC type components complemented by reconfigurable elements (such as FPGA, DSP, etc.)
iii) ASIC type components designed for firmware updates

It is expected that typical commercial implementations will not rely on the highest level of flexibility due to cost constraints, but rather apply a combination of ASIC type components and reconfigurable elements.

Figure 1 presents a typical example representation of a transmission chain which is comprised of components A, B, C, D, E, F.

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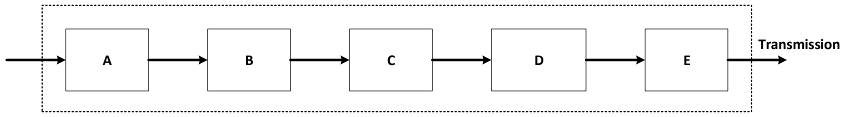

Figure 3: Example representation of components of a transmission chain

It is assumed that a manufacturer may choose to enable (third party) software developers to replace one or many of these components with novel software components. Figure 2 illustrates the replacement of component B through a novel implementation by (third party) software developers. This step may be motivated, for example, by an identification of security challenges in the corresponding component.

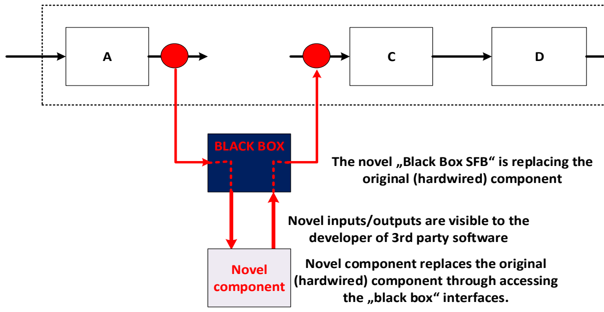

Figure 4: Example replacement of a component through interfacing with novel standard functional block (SFB) provided by a (third party) software provider

The upper examples illustrate how a limited set of reconfigurable elements can mitigate (security) vulnerabilities. Also, such reconfigurable elements may be employed in order to selectively add new functionalities of, for example, a new 3GPP release or IEEE amendment – instead of a full software-based implementation of the entire stack.
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<tr>
<td>Pre-Conditions</td>
<td>

Vehicle OEM, equipment manufacturer or chipset vendor publishes a software update for a target list of HVs.
Drivers, passengers or automated HV system discovers or decides that a radio software or firmware update should be requested.

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<tr>
<td>Main Event Flow</td>
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Vehicle OEM, equipment manufacturer or chipset vendor posts a mandatory radio software or firmware update and notifies targeted HVs of the new version.
HV receives notification and starts downloading the radio software or firmware update.
HV downloads segments of the radio software update at opportune moments that do not affect the performance of safety features.
If HV completes downloading the posted radio software update
<ol type="a">
HV installs the downloaded radio software update at a convenient time
HV self-tests if the radio software update allows reliable and high-quality radio communication operations
Declaration of conformity is issued after the update has completed

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</table>

	• HV notifies the vehicle OEM, equipment manufacturer or chipset vendor of the applied radio software update version.

Alternative Event Flow	• Driver, passenger or automated HV system requests a radio software or firmware update.
	• HV starts downloading the radio software or firmware update.
	• HV downloads segments of the radio software update at opportune moments that do not affect the performance of safety features.
	• If the HV completes downloading the requested radio software update
	  ○ HV installs the downloaded radio software update at a convenient time
	  ○ HV self-tests if the radio software update allows reliable and high-quality radio communication operations
	  ○ Declaration of conformity is issued after the update has completed
	
	HV notifies the vehicle OEM, equipment manufacturer or chipset vendor of the applied radio software update version.

Post-Conditions	Mandatory or optional software update are deployed on targeted HVs.
Information Requirements	• HV's list of current radio software feature versions • Vehicle OEM, equipment manufacturer or chipset vendor list of radio features and standard releases • HV's radio software update download progress • Declaration of conformity issued after radio software has been updated

User Story	**Detailed description, specifics and main differences to the user story in the main template**
Upgrade of Feature-Set	Radio air interface evolves and new features are added. The required time for equipping all vehicles with the updated features may be up to one year.
Addressing Vulnerabilities	Identified vulnerabilities such as bad design choices, protocol weaknesses, etc. need to be addressed and the affected functionality needs to be modified. Depending on the criticality, the required time for equipping all vehicles with the updated features may be between one day and up to one year. In particular for critical security leaks, a one-day update time for the entire fleet may be required.

User Story #1 **(Upgrade of Feature-Set)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	Within network service	In principle, the user story is applicable in the network service provider coverage area.

		provider coverage	
Information Requested/Generated	Quality of information/ Information needs	Up to 200 MB per update	Depending on the size of the feature-set in the new release, several blocks of the radio system need to be upgraded with a database possibly attached to the feature-set. Normally, the process of downloading the radio software update occurs in the background and should defer to more latency sensitive applications.
Service Level Latency	[ms]	N/A	Software updates themselves are not latency sensitive.
Service Level Reliability	%	99	Radio software updates should successfully transfer but this can occur over an extended period, as above. Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given to a more rapid download when in range.
Velocity	[m/s]	U19.4	This is a typical maximum city speed (70 km/h), where it will be helpful to collect radio software updates over time. Note that a consistent download rate is not required, since the download may collect parts of the software image as available, and pause and continue downloading as needed.
Vehicle Density	[vehicle/km^2]	1500 vehicles/km^2	Ideally, with all vehicles in a dense area employing reconfigurable radio systems, all should be updated almost simultaneously.
Positioning	[m]	30 (1σ)	Depending on regional radio regulations, the vehicle only needs to know in which region it is located.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/ Yes/No	Different OEMs may employ different providers of radio software. Radio regulations need to determine under which conditions a new release can be deployed.

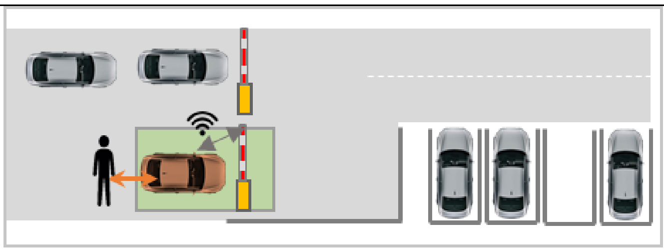
User Story #2 (Addressing Vulnerabilities)			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	Within network service provider coverage	In principle, the user story is applicable in the network service provider coverage area.
Information Requested/Generated	Quality of information/ Information needs	Few MB up to 100 MB	Depending on which software module the vulnerability is encountered, the specific module needs to be replaced.
Service Level Latency	[ms]	1 hour to deliver 'critical update required' message	The most stringent requirement is to deliver the 'critical update required' message. The human driver is still responsible for safe vehicle operation.
Service Level Reliability	%	99	Radio software updates should successfully transfer but this can occur over an extended period, as above. Exceptions would be when a vehicle is persistently out-of-range (for example, in long-term underground parking), or only sporadically within range (such as a farmer who only occasionally drives into town), in which case priority may be given for a more rapid download when in range.
Velocity	[m/s]	Up to 19.4	This is a typical maximum city speed (70 km/h), where it will be helpful to collect radio software updates over time. Note that a consistent download rate is not required, since the download may collect parts of the software image as available, and pause and continue downloading as needed.
Vehicle Density	[vehicle/km^2]	1500/km^2 10%-30% of the vehicles	By assuming a dense urban environment, many vehicles need to have their system updated due to a high penetration of the same radio system.
Positioning	[m]	30 (1σ)	Depending on regional radio regulations, the vehicle only needs to know in which region it is located.

Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Different OEMs may employ different providers of radio software. Radio regulations need to determine if and when the replacement of the vulnerable radio system block can be deployed.

5.3 Convenience

5.2.1 Automated Valet Parking – Joint Authentication and Proof of Localisation

Use Case Name	**Automated Valet Parking – Joint Authentication and Proof of Localisation**
User Story #1	• A manual driver drops off the vehicle in a designated transition zone for autonomous parking in a parking facility. • The transition zone is separated from the parking area, for example by a barrier which should open for validated vehicles only. After a successful authentication and proof of the vehicle's position, the vehicle is accepted for autonomous parking (i.e. the barrier opens for this vehicle).
Category	Convenience, autonomous driving, parking.
Road Environment	Parking areas.
Short Description	• The parking facility wants to ensure that only authorized vehicles get access to the (autonomous) parking area The infrastructure verifies a vehicle's position claim and gives the vehicle access to the parking facility in case of success.
Actors	Vehicle, parking infrastructure.
Vehicle Roles	Autonomous vehicle: autonomous parking in approved facilities.
Road/Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	Parking infrastructure that support driverless parking.
Goal	Access control to a parking facility for autonomous vehicles.
Needs	Not applicable.
Constraints/ Presumptions	Not applicable.
Geographic Scope	Parking areas validated for autonomous parking.

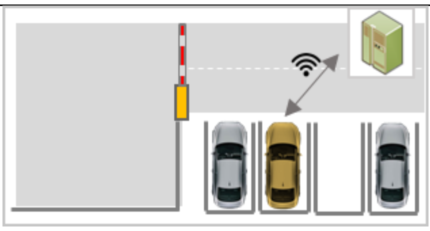
Illustrations	
Pre-Conditions	The vehicle is dropped off by a manual driver in the transition zone and ready for autonomous parking.
Main Event Flow	• After the vehicle is placed in the assigned transition zone by a manual driver, the vehicle asks for access to the parking facility on a communication connection. • The infrastructure verifies the position of the vehicle. • In the event of a successful check, the vehicle is admitted for autonomous parking.
Alternative Event Flow	If the proof of localisation fails, the driver is informed and access to the driverless parking function has to be denied.
Post-Conditions	The authenticity and position of the vehicle is verified.
Information Requirements	Not applicable.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	HV to Parking Garage: 50	Assuming direct communication, communication is needed between a vehicle and a barrier. Assuming network connection, no value is specified.
Information Requested/Generated	Quality of information/ Information needs	Data rate is very low, we assume 1000 bytes in 500 ms, resulting to 16 Kbps	Proof of identity by the vehicle. The position of the vehicle might come from the vehicle or be inferred by the infrastructure.
Service Level Latency	[ms]	500	There is no particular constraint on Service Level Latency, hence the high number.
Service Level Reliability	%	99	The failure probability is so low that there is no significant delay in entering the parking structure.
Velocity	[m/s]	Moving in drop-off zone to barrier:	25 km/h is assumed as the maximum velocity.

		6.9	
Vehicle Density	[vehicle/km^2]	50	It is assumed that there is only one drop-off zone in the given km^2 and that 50 vehicles are lining up in that zone.
Positioning	[m]	1 (3σ)	Relative positioning between a barrier and a vehicle.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability due to different OEMs. Regulation is needed, e.g. maximum speed in drop-off area. A standardised protocol is needed for this Use Case.

5.2.2 Automated Valet Parking (Wake Up)

Use Case Name	**Automated Valet Parking (Wake Up)**
User Story #1	• A parked sleeping vehicle in a parking facility should be autonomously moved for (re)parking (e.g. charging) or pick-up. • For this purpose, the vehicle receives a wake-up call upon which the autonomous drive is prepared.
Category	Convenience.
Road Environment	Parking areas.
Short Description	• An application running on infrastructure sends a wake-up call to a specific vehicle. The wake-up call can be sent using the Uu interface on cellular networks or using the PC5 interface. Both options are required as it is assumed that not all underground parking garages will have cellular coverage form all operators. In case of PC5, we assume PC5 infrastructure components in the parking garage. • Upon receiving the wake-up call, the vehicle should start preparations for an autonomous movement. • Other vehicles should ignore the wake-up call. • The vehicle’s ‘listening to wake-up calls’ process should consume as little energy as possible. Integrity/availability/authenticity/confidentiality all have to be ensured.
Actors	Vehicle, parking application.
Vehicle Roles	Autonomous vehicle: parking in approved facilities.
Road/Roadside Infrastructure Roles	Not applicable.
Other Actors’ Roles	Automated Valet Parking Infrastructure: local PC5 infrastructure to communicate with parking vehicles.

Goal	Wake up sleeping autonomously driving vehicles for the purpose of movement.
Needs	The autonomous vehicle needs to receive the wake-up message.
Constraints/ Presumptions	• C-V2X communication between vehicle and infrastructure. • Possibility to address a specific vehicle. • Possibility to verify the authenticity of the wake-up call. • Minimum energy consumption, i.e. power efficiency on receiver side is crucial.
Geographic Scope	Parking areas supporting autonomous parking, including parking areas with cellular coverage and those where sidelink communication to the local PC5 infrastructure is available.
Illustrations	
Pre-Conditions	• Sleeping/parked vehicle in parking area. • Trigger for vehicle movement.
Main Event Flow	• Upon a trigger for a vehicle movement, the parking application sends a wake-up call including an identifier for the addressed vehicle. • This can be delivered over cellular Uu or local PC5 interface; in the latter case, local PC5 infrastructure is required. • The addressed vehicle checks the authenticity of the wake-up call and starts with preparations for the autonomous movement. • The vehicle confirms the receipt of the wake-up call.
Alternative Event Flow	• The vehicle ignores wake-up calls which could not be authenticated. • The parking application informs the driver if the wake-up is not confirmed.
Post-Conditions	The parking application receives a confirmation of the wake-up call.
Information Requirements	Not applicable.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	For direct communication: 1000 For cellular: N/A	In the direct communication case, a distance of 1000 m should be provided to equip parking structures adequately.

			When cellular communication is used, the range is indicated as N/A as a larger range is possible.
Information Requested/Generated	Quality of information/ Information needs	Authenticated wake-up signal	Data rate 3.2 Kbps
Service Level Latency	[ms]	500	This is a very loose requirement because all automated driving actions occurring after the wake-up call need more time to initiate.
Service Level Reliability	%	99	This is the probability that the car owner or infrastructure initiate a wake-up call and the vehicle does not reply within the Service Level Latency. This should be high enough to prevent the user from losing trust in the service.
Velocity	[m/s]	0	The car is parked during a wake-up call.
Vehicle Density	[vehicle/km^2]	15,150	Assuming a parking space is 2.30 m wide and 5 m long (plus 3.5 m on each side to reach the spot), approximately 434 x 117 (50,500) parking spots on one square kilometre are needed. Assuming six levels that comes to an estimated 303,000 spots. The total number of vehicles that need to be woken up in the same area can be estimated. Assume between 1% and 5% of the vehicle parking spaces need to be 'woken up' simultaneously, the parking area coverage comes to 3030-15,150.
Positioning	[m]	N/A	Not applicable.
Power Consumption	[mW]	30	Assume 30 mW for the ECU to keep this service available for two weeks.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/No/Yes	Interoperability due to different OEMs and different infrastructures. Regulation is not needed. A standardised protocol is needed for this Use Case.

5.2.3 Awareness Confirmation

Use Case Name	**Awareness Confirmation**

User Story #1	The host vehicle is sending out messages. This can include basic safety messages and future, more evolved message types. Further, this Use Case is not limited to PC5 sidelink communication but also applicable in transmission over the Uu interface. The host vehicle indicates whether it would like to receive confirmation on its messages and sets properties accordingly, such as those described in detail below. The host vehicle receives confirmation from the remote vehicles and uses this for one or more of the following purposes: • In a manually driven vehicle, indicate the general V2X penetration level of the current surroundings (e.g. low, medium, high). • In a manually driven vehicle, indicate which remote vehicles confirmed awareness of the host vehicle, or alternatively, those which have not. This can be shown visually to the driver using a heads-up display. In an automatically driven vehicle, the host vehicle adapts its driving style according to the V2X penetration level it has received from the surrounding remote vehicles.
Category	Convenience.
Road Environment	Urban, highway.
Short Description	• A host vehicle sends out messages, e.g. with a regular cadence. • It indicates for which of these messages it would like to receive confirmation and sets according properties. It receives confirmations on the messages and processes these.
Actors	Vehicle.
Vehicle Roles	Host vehicle and remote vehicles.
Road/Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	Host vehicle perceives awareness of remote vehicles.
Needs	The host vehicle needs to receive confirmation messages from remote vehicles.
Constraints/ Presumptions	The host vehicle needs to implement or set properties (functionality) to send/receive confirmation messages. The remote vehicles need to implement functionality to send confirmation messages according to the requested properties.
Geographic Scope	Anywhere.
Illustrations	Not applicable.
Pre-Conditions	The host vehicle sets the following properties for confirmation messages: • Type of message: for which messages should confirmation be sent to the host vehicle, e.g. BSM.

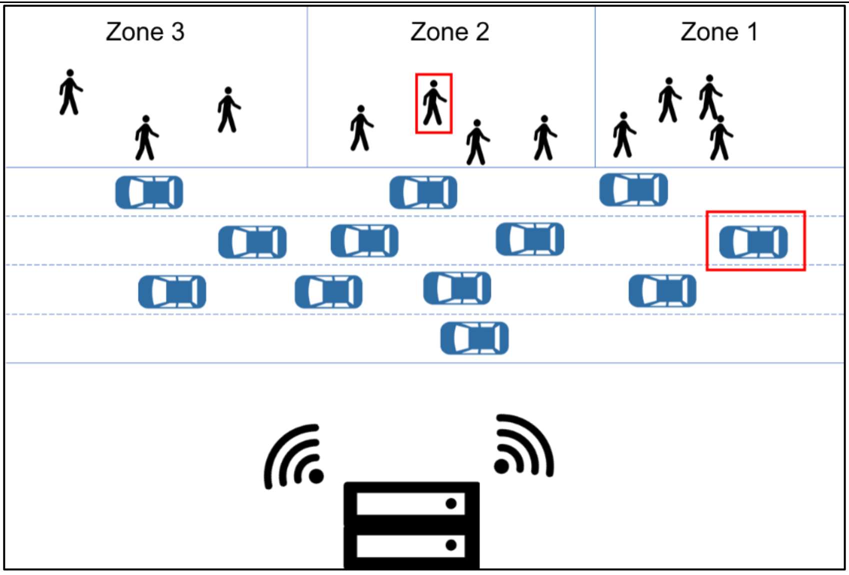
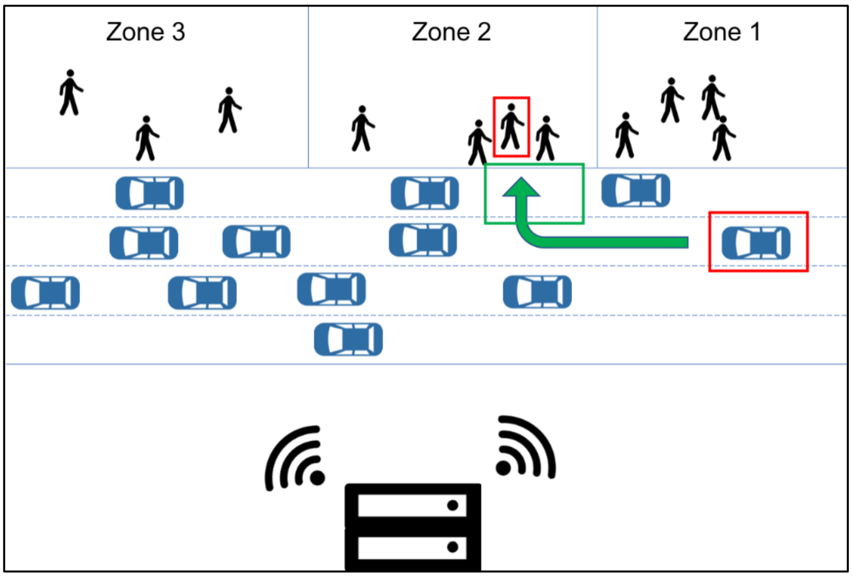
	• Feedback rate control: for a given remote vehicle, specify the cadence of feedback, e.g. 'every second message'. • Maximum confirmation latency: delay between sending a message and receiving confirmation of it. • Vehicle sampling: specify the maximum distance, time offset or probabilistic feedback to reduce the number of remote vehicles sending confirmation to the remote vehicle. • Reliable channel: assuming that there are reliable and unreliable logical channels, indicate whether feedback should be sent over a reliable or an unreliable logical channel. • Transmission type: request confirmation for multicast, broadcast, and unicast messages. • Signalling reduction methods: use methods to reduce the channel load, e.g. by piggybacking the reply on the next payload. • Validity period: statement on how long these properties would be deemed current. The host vehicle sends out a confirmation property message, which informs its surroundings about these properties. Note: it should not be possible to request confirmation messages in congested scenarios (i.e. when the channel load exceeds a certain threshold); a rejection message should be sent promptly.
Main Event Flow	• The remote vehicles receive messages from the host vehicle, no confirmation is sent. • Once the remote vehicles receive a confirmation property message from the host vehicle, they decide whether to send confirmations and, if affirmative, create and send them according to the defined properties. • The vehicle receives the confirmation message and uses it for one or more of the following purposes: (a) in a manually driven vehicle, to indicate the V2X safety level of the current surroundings, (b) in a manually driven vehicle, to indicate which remote vehicles confirmed awareness of the host vehicle and which did not. This can be implemented using a heads-up display, (c) in an automatically driven vehicle, the host vehicle adapts its driving style according to the level of confirmation it has received from the surrounding remote vehicles. Note: this Use Case does not foresee confirmation on confirmation messages (ACK of ACK).
Alternative Event Flow	Not applicable.
Post-Conditions	The HV stops sending messages (the payload messages, e.g. BSM). Remote vehicles stop sending confirmation messages as they do not receive any messages from the host vehicle.
Information Requirements	Car sensor data to match confirmations with surrounding situation.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	1000	The range for messages related to awareness confirmation shall not be below the range of regular messages, such as BSMs.
Information Requested/Generated	Quality of information/ Information needs	Request for confirmation itself as well as corresponding settings, such as Type of Message, Feedback Rate, etc.	Maximum 40 Kbps, vehicle requesting confirmation from all messages. Frequency requirements, maximum 50 in the case of an event.
Service Level Latency	[ms]	According to settings in request Typical value: 20	The latency between sending a message and receiving its confirmation. A maximum value in the request that can help the receiver of the message to decide how fast a confirmation needs to be sent out.
Service Level Reliability	%	99 for regular and 99.9 for reliable channel	The settings allow for confirmation messages to be sent over a regular channel or a reliable channel. The Service Level Reliability is set accordingly.
Velocity	[m/s]	138.8, what corresponds to 500 km/h	As this is a general concept, it is not advisable that other Use Cases build on it, so it describes the maximum relative speed between two cars.
Vehicle Density	[vehicle/km^2]	9000	Confirmations should not be sent in congested situations, hence the maximum vehicle density is set to 9000 vehicle/km^2. This is an intermediate figure based on vehicle density values of 4500 (highway), 9000 (rural), and 12,000 (urban).
Positioning	[m]	1.5 (3σ)	The positioning must allow to separate the vehicles from each other, such that it can be identified which vehicle sends what.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability due to different OEMs.

			Regulation is needed, e.g. for setting limits to the properties. A standardised protocol is needed.

5.2.4 Cooperative Curbside Management

Use Case Name	**Cooperative Curbside Management**
User Story #1	A pedestrian and a vehicle are planning a pick-up at a crowded curbside area. Before entering the area, they indicate to their respective devices (e.g. vehicle, smartphone, etc.) that they are looking for each other. The curbside area is managed by a certified and trusted traffic management entity (TME) infrastructure node that has knowledge of all active pick-up sessions. This TME transacts with the pedestrian and vehicle, and designates a specific pick-up zone along the curbside when it determines that they are both in the vicinity and there is room for the pick-up to take place. When designating this dynamic pick-up zone, the TME takes into account all other groups whose transactions it is facilitating. This designated pick-up zone is communicated to both the vehicle and the pedestrian, which then both communicate with each other directly until pick-up is confirmed.
User Story #2	If applicable.
Category	Convenience.
Road Environment	Urban.
Short Description	• Vehicle and pedestrian are attempting to meet at crowded curbside area. • Certified infrastructure node designates pick-up area based on other active pick-ups. • Shares this information with vehicle and pedestrian to facilitate interaction. • Vehicle and pedestrian meet in area, confirm pick-up to infrastructure node.
Actors	Vehicles, pedestrians, infrastructure.
Vehicle Roles	Host vehicle, autonomous or human-driven, will follow pathing instructions from TME to complete curbside pick-up of pedestrian.
Road/Roadside Infrastructure Roles	Mediation of interaction between vehicle and pedestrian, designation of pick-up zones, dictation of traffic flow.
Other Actors' Roles	Pedestrian must follow instructions to reach vehicle pick-up zone and load.
Goal	Improve efficiency and safety of densely populated curbside pick-up areas.
Needs	Certification of infrastructure, cooperation of vehicles.

Constraints/ Presumptions	Not Applicable.
Geographic Scope	Densely-populated areas with curbside pick-up area.
Illustrations	 
Pre-Conditions	HV and pedestrian know each other's identifiers, infrastructure node is certified and trusted.
Pre-Conditions RVs	Not applicable.
Main Event Flow	• Pedestrian and HV arrive at pick-up area. • Pedestrian and HV individually inform the TME who they are looking for. • TME determines there is a match. • TME designates pick-up area along curbside based on positions of RVs and active pick-ups. • TME communicates pick-up area to HV and pedestrian.

	• HV and pedestrian communicate directly with each other until meeting. • HV and pedestrian confirm to TME that pick-up has been completed.
Alternative Event Flow	HV could be told to wait outside the pick-up area until pedestrian arrives or if traffic is too heavy to bring in other vehicles.
Post-Conditions	HV could be informed of a viable exit route from the pick-up area that does not conflict with active pick-up instructions for RVs.
Information Requirements	• Vehicle/pedestrian pick-up IDs. • Data defining dynamic pick-up zones.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	800 10,000	Range needs to be long enough to communicate pick-up instructions to approaching vehicles (i.e. just before they reach pick-up lanes). Longer range is necessary to initiate pick-up with a vehicle that is still far away from curbside area.
Information Requested/Generated	Quality of information/ Information needs	(Sequence of messages including Acknowledgment messages)	Data from a HV and pedestrian will be low in volume (mostly identifiers); data from TME will be more intense at peak, including granular vehicle path data along with metadata such as time-to-live (TTL).
Service Level Latency	[ms]	100 5000	As a vehicle approaches the curbside area, there is some time for the TME to send a 'coordination message' before it formally enters the densely crowded zone. When a vehicle is initially indicating to a TME that it will be executing a curbside manoeuvre, it may still be several kilometres away, in which case the messages are not urgent (no 'time urgency').
Service Level Reliability	%	99.9	Dropped packets or connections could result in vehicle trajectory conflicts.
Velocity	[m/s]	22.4	(80 km/h) Some pick-up areas have high-speed approaches where vehicle

			communication with a TME will begin (e.g. highway off-ramp, airport access road).
Vehicle Density	[vehicle/km^2]	2000	Assumes 1 km x .25 km U-shaped pick-up area with 4 lanes, and vehicle spaces only 1 m apart, which fits 410 cars per lane * 4 lanes = 1640, plus extra cars entering or leaving the pick-up area.
Positioning	[m]	1 (3σ)	Since vehicles are in close proximity to one another, positioning must be extremely precise to prevent overlapping vehicle paths or pick-up areas.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/No/Yes	Interoperability due to different OEMs and mobile device manufacturers. The Use Case is largely driven by efficiency and convenience, so it may only be deployed as needed in areas with extremely high-volume traffic. A standardised protocol is needed.

5.2.5 Cooperative Lateral Parking

Use Case Name	**Cooperative Lateral Parking**
User Story #1	The host vehicle identifies a free parking space in a longitudinal parking scenario. It sends information to the vehicles in its vicinity to inform them of the planned parking action and asks them to 'make room' for this purpose. To this end, it includes sensor information which allows the parked vehicles to identify themselves and provides information on the expected duration of the manoeuvre, and detailed information on how much space is needed and the precise location. • In a manually driven vehicle, the driver can request additional parking space. • In a vehicle with driver assistance systems, the parking assistant can assess whether a parking space becomes viable if additional space is provided by the surrounding vehicles. • In an automatically driven vehicle, the host vehicle decides which parking spot to take and whether additional space needs to be requested from the other vehicles.
Category	Convenience.
Road Environment	Urban.
Short Description	• A vehicle would like to perform longitudinal parking and needs more space.

	• It asks surrounding vehicles to 'squeeze together' and thus make more space temporarily; this is a recursive scheme, if one vehicle cannot create sufficient space, it asks the next vehicle to move as well. • Once completed, all remote vehicles return to their original space, except for leaving space for the newly parked vehicle.
Actors	Vehicle.
Vehicle Roles	Host vehicle and remote vehicles.
Road & Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	Increase speed and convenience of parking manoeuvre.
Needs	Remote vehicles need to cooperate.
Constraints/ Presumptions	Remote vehicles need to wake up on the request message and need to be able to perform simple driving manoeuvres (driving closer to another vehicle).
Geographic Scope	Anywhere.
Illustrations	Not applicable.
Pre-Conditions HV	Host vehicle is arriving at a zone where it is planning to park.
Pre-Conditions RVs	All participating remote vehicles are parked, but are capable of receiving C-V2X messages and wake-up based on these messages.
Main Event Flow	• Host vehicle sends information that it would like to park at a given location. • Receiving vehicles send awareness confirmation along with their willingness to participate. • Host vehicle decides whether parking is possible. • If possible, host vehicle sends sensor information such that vehicles in front and behind the parking space can identify themselves; and the host vehicle sends information on the duration and exact space requirements (front/rear). • Remote vehicles react accordingly: create the needed longitudinal space to the HV and inform the host vehicle that it can start the parking manoeuvre. • Host vehicle sends confirmation that parking action is complete.
Alternative Event Flow	• Host vehicle decides whether parking is possible. • Host vehicle sends information that it would like to park at a given location. • Receiving vehicles send awareness confirmation and willingness to participate. • If possible, host vehicle sends sensor information such that vehicles in front and behind the parking space can identify themselves; and the host vehicle sends information on the duration and exact space requirements (front/rear).

	• RVs begin recursive scheme of determining the feasibility of requested manoeuvre. • One of the RVs required for the manoeuvre declines the request. • Option 1: Vehicles decide on a solution without involving the vehicle which declined the request. • Option 2: Host vehicle sends acknowledgement and aborts the manoeuvre.
Post-Conditions	Remote vehicles coordinate to return to a position close to original position.
Information Requirements	Car sensor data.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	50	The range of the messages is very low as only vehicles in the direct surrounding of the parking spot need to be reached.
Information Requested/Generated	Quality of information/ Information needs	27 Mbps	Assuming an ultrasonic sensor with 38,400 baud rate with 16 Bit resolution = 614.4 Kbps per sensor. For ten front (five) and rear (five) sensors, the data rate required on the direct links would be 6 Mbps. The data may be compressed at a rate of 2, which yields 3 Mbps. Compressed video camera data from two cameras (one at the front and one at the rear of the host vehicle) results in a data rate of 24 Mbps. Hence, the required data rate of both sensor types on the direct links is about 27 Mbps.
Service Level Latency	[ms]	100 manoeuvre 10 for cooperative manoeuvre	100 ms for messages preparing the manoeuvre. 10 ms while multiple vehicles are performing a cooperative manoeuvre.
Service Level Reliability	%	99.9	Dropped packets or connections could result in vehicle conflicts, during a cooperative manoeuvre.
Velocity	[m/s]	1.38	Vehicles move very slowly during parking manoeuvres (corresponding to 5 km/h).
Vehicle Density	[vehicle/km^2]	1000	Downscaled value of 12,000 vehicles that is used as the maximum density estimated in a dense urban grid. This

			number is calculated for one lane in each direction and 20 m inter-vehicle distance.
Positioning	[m]	0.2 (3σ)	Relative positioning longitudinally.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability due to different OEMs. Regulation is needed, e.g. for setting limits to the properties. A standardised protocol is needed.

5.2.6 In-Vehicle Entertainment (IVE) – High-Definition Content Delivery, On-line Gaming and Virtual Reality

Use Case Name	**In-Vehicle Entertainment (IVE)**
User Story	High-definition (HD) content delivery, on-line gaming and virtual reality (VR)
Category	Convenience.
Road Environment	Intersection, urban, rural, highway, others.
Short Description	The Use Case concerns entertainment content delivery to the passengers of a moving or stationary vehicle. It is applicable to both automated and non-automated vehicles, where in the latter the driver is restricted in the content he/she is allowed to consume. For cars, up to four occupants can consume high-definition and immersive entertainment media content while the vehicle is stationary or moving. For buses and people transporters up to 30 passengers can consume the same content under similar conditions. Each occupant may be interested in different content which may include video, gaming, virtual reality, office work, online education, advertisement, etc. Contextual information can be embedded in the entertainment media depending on the location of the HV.
Actors	Host vehicle, HV owner, operator or manager, passengers, service providers (e.g. wireless network operators, road operators, streaming and gaming services, a combination of them, and others).
Vehicle Roles	Host vehicle is the vehicle where the passengers consume the content.
Roadside Infrastructure Roles	The roadside infrastructure does not necessarily play a direct role in this user story.
Other Actors' Roles	• The passengers are the consumers of the HD content and potentially possess a business relationship with the service provider and/or with the HV owner, operator or manager. • Service providers are the originators of the content and/or wireless connectivity providers and possess a business relationship with the passenger and/or with the HV owner, operator or manager.

	• HV owner, operator or manager is an entity that has a business relationship with the service providers and/or with the passengers, or it is a passenger itself.
Goal	To supply and deliver on-demand HD entertainment content to the HV passengers.
Needs	Passengers want entertainment while commuting and travelling for long periods of time, but also while HV is parked or stopped in traffic.
Constraints/ Presumptions	• The operation of in-vehicle entertainment should not compromise safety. • HV owner, operator, manager or passengers has established business relationships with other mobile wireless devices, but potentially needs to extend this relationship to encompass the employed HV to the multi-streaming of the HD content. • HV owner, operator, manager or passengers and service providers already have established business relationships (subscription, contract, pay-per-view, on-demand, B2B, B2C, etc.) that support the multi-streaming of HD content. • HV and service providers can establish a secure communication link. • HV and service providers should be able to mutually authenticate.
Geographic Scope	National or international, depending on the areas where the service provider has permission and is able to provide the service, e.g. due to IPR, copyright, censorship, law, etc.
Illustrations	Not applicable.
Pre-Conditions	• Service providers have access to the means allowing them to stream, store, transcode and distribute the HD content, including live transmissions of events. • Service providers are able to adjust QoS and QoE according to the environment where the HV is located, even at high speeds. • HV is equipped with onboard devices that provide the means to verify the existence of a business relationship with the service providers for wireless connectivity and HD content. • HV is equipped with onboard devices that provide the means to each passenger individually accessing the HD content data. • HV is equipped with onboard devices that provide the means to process and deliver the video and audio data of the HD content to each passenger individually. • Alternatively, passengers can bring individual handheld devices that provide the means to process and deliver the video and audio data of the HD content. • Passengers are individually provided with the means to choose which HD content they are interested in. • Service providers can fulfil IPR, copyright, censorship and other legal requirements to supply the requested content. • HV owner, operator, manager or one of the passengers can select the service providers for wireless connectivity from a list (1 to N), and the service provider for HD content (1 to N) (e.g. ‘customer choice’).

Main Event Flow	• A communication link between the HV and wireless service provider is established. • The new communication link for the HD content does not disrupt the communication link for other Use Cases involving safety and other mission-critical services. • A business relationship with a HD content service provider is established or verified (Note: this does not preclude wireless and HD content service providers from being the same entity). • Each passenger individually chooses which HD content he/she is interested in before or after entering the car. • Individual passengers request access to the chosen HD content each time they enter the car. • Service providers identify each passenger's individual choices and the HV's location. • Service providers check if the content is available and/or has permission to be accessed in the region where the HV is located and if the HV is authorised to receive the HD content. • Service providers makes the HD content available to individual passengers. • Each passenger individually accesses and plays the HD content at his/her own convenience. • Each passenger stops or pauses the HD content at his/her own convenience.
Alternative Event Flow	• A communication link between the future passengers' handheld and desktop devices and wireless service providers is established. • A business relationship with a HD content service provider is established or verified (Note: this does not preclude wireless and HD content service provider from being the same entity). • Each future passenger individually chooses (on a handheld or desktop device) which HD content he/she is interested in before entering the car. • Each future passenger individually requests (on a handheld or desktop device) access to the chosen HD content before entering the car. • Each service provider identifies each future passenger's individual choices and location. • Each service provider checks if the content is available and/or has permission to be accessed in the region where the future passenger is located. • Each service provider makes the HD content available to each individual future passenger. • Passengers enter the HD and decide if they wish to continue accessing the HD content on handheld or onboard devices. • A communication link between HV and wireless service provider is established. • A business relationship with the HD content service provider is established or verified, now for the HV connection (Note: this does not precludes wireless and HD content service provider from being the same entity). • Each passenger individually accesses and plays the HD content at his or her own convenience before or after entering the HV.

	• Each passenger individually stops or pauses the HD content at his or her own convenience before or after entering the HV.
Post-Conditions	The HD content chosen and played (or not) by the passenger may be partially or temporarily stored in the HV.
Information Requirements	HD content data, HV authentication and identification data, passengers' preferences, choices and identification data, HV location.

User Story	Detailed description, specifics and main differences to the user story in the main template.
High-End Service for Cars	The extreme case that includes up to four consumers of HD 8 k video content, including gaming with higher latency constraints and interactive, immersive entertainment, such as VR data streaming.
Low-End Service for Cars	The relaxed case that includes two content consumers of HD 4 k video streams and does not support low latency gaming services.
Bus Passenger Service	Another extreme case that includes up to 30 consumers of HD video content but no low latency services such as gaming and immersive entertainment.

User Story #1 **(High-Definition (HD) Content Delivery, On-line Gaming and Virtual Reality – High-End Service for Cars)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Depends on the new or alternative definition of range. In principle, the Use Case is applicable to the service provider coverage area.
Information Requested/Generated	Quality of information/ Information needs	Quality of Experience 4 streams of 8 k resolution video with estimated up to 250 Mbps per stream	The information need reference is also applicable to immersive entertainment, such as virtual reality (VR). The instantaneous data rate will probably vary during operation.
Service Level Latency	[ms]	20	This is the maximum latency tolerable for online gaming and for a VR or augmented reality (AR) immersive experience. For on-demand services a higher latency may be tolerable. (See alternative user story).
Service Level Reliability	%	99	The reliability here should be sufficient to guarantee Quality of Experience (QoE) for both gaming and VR/AR.

Velocity	[m/s]	69.4	Maximum speed on highways is 250 km/h and the content should also be delivered at all possible speeds up to this maximum.
Vehicle Density	[vehicle/km^2]	500 vehicles/km^2	Assumes an overall vehicle density of 1500 vehicles/km^2 and that one third of them have up to four passengers accessing HD content.
Positioning	[m]	30 (1σ)	It is typically enough for the service provider to identify in which street/road and approximate position along this street/road.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/No/No	The content format and content distribution platform (service level) does not need to be standardised.

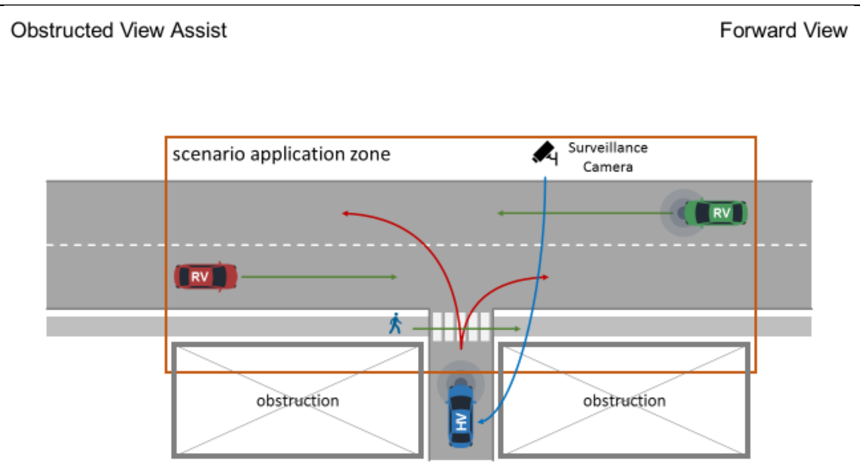
User Story #2 **(High-Definition (HD) Content Delivery – Low-End Service for Cars)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Not applicable.
Information Requested/Generated	Quality of information/ Information needs	Quality of Experience 2 streams of 4 k resolution video with estimated 50 Mbps per stream	The requirement here is that the passengers served should achieve an absolute minimum QoE.
Service Level Latency	[ms]	150	This is the maximum latency supported for interactive video, such as video conferencing.
Service Level Reliability	%	90	The reliability here should only meet minimal requirements for video streaming with guaranteed QoE.
Velocity	[m/s]	41.6	The low-end variant may be applicable to vehicles that cannot reach very high speeds (up to 150 km/h).
Vehicle Density	[vehicle/km^2]	500 vehicles/km^2	Assumes an overall vehicle density of 1500 vehicles/km^2 and that one third of them

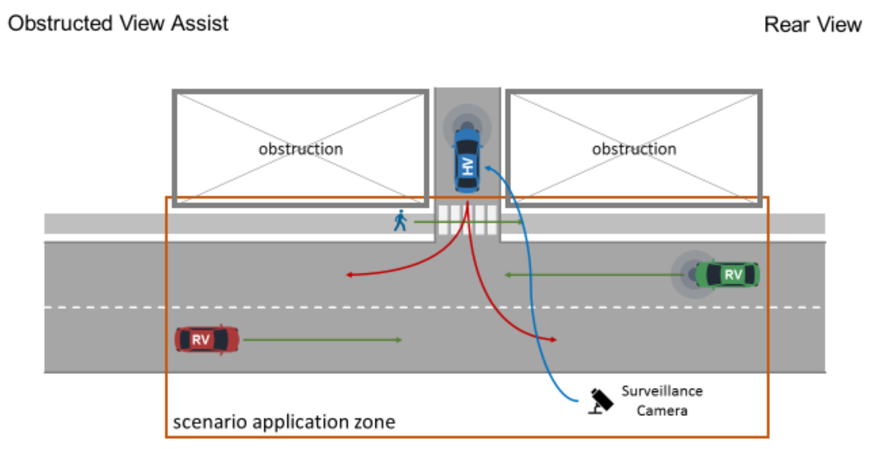
			have up to two passengers accessing HD content.
Positioning	[m]	50 (1σ)	It is typically enough for the service providers to identify in which street and the approximate position along this street.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/ No/No	The content format and distribution platform (service level) do not need to be standardised.

User Story #3 **High-Definition (HD) Content Delivery – Bus Passenger Service**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Depends on the new or alternative definition of range. In principle, the Use Case is applicable in the service provider coverage area.
Information Requested/Generated	Quality of information/ Information needs	Quality of experience Up to 30 streams of 4 k resolution video with estimated up to 50 Mbps per stream	The requirement here is that the passengers served should achieve an absolute minimum QoE.
Service Level Latency	[ms]	150	This is the maximum latency supported for interactive video, such as video conferencing.
Service Level Reliability	%	90	The reliability here should only meet minimal requirements for video streaming with guaranteed QoE.
Velocity	[m/s]	27.8	A fully occupied bus would have a limited maximum speed (up to 100 km/h).
Vehicle Density	[vehicle/km^2]	30 vehicles/km^2	Assumes an overall vehicle density of 1500 vehicles/km^2 and that 1/50 of them are buses that have up to 30 passengers accessing HD content.
Positioning	[m]	50 (1σ)	It is typically enough for the service providers to identify in which street/road

			and approximate position along this street/road.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/No/No	The content format and distribution platform (service level) does not need to be standardised.

5.2.7 Obstructed View Assist

Use Case Name	**Obstructed View Assist**
Category	Convenience.
Road Environment	Intersections, e.g. in rural and urban environments.
Short Description	HV is provided an alternate when faced with an obstructed view.
Actors	CCTV cameras (for User Story 1 only), host vehicle, remote vehicles (for User Story 2 only).
Vehicle Roles	HV represents the vehicle with an obstructed view. In User Story 2, remote vehicles provide a video stream to support HV.
Roadside Infrastructure Roles	Surveillance cameras provide alternate views where installed.
Other Actors' Roles	Not applicable.
Goal	Provide HV with an alternate view of the obstructed road segments.
Needs	HV needs an alternative view when an obstructed view prohibits the HV from proceeding safely. This view can be provided by CCTV (User Story 1) or other cars (User Story 2).
Constraints/ Presumptions	Surveillance cameras (and cars, for User Story 2) can share video.
Geographic Scope	Global.
Illustrations	



Pre-Conditions	• HV is stopping because of an obstructed view.
	• The 'forward view' scenario application zone is determined from
	  ○ HV's location
	  ○ HV's intention to proceed forward
	  ○ lane designations and geometry
	• The 'rear view' scenario application zone is determined from
	  ○ HV's location
	  ○ HV's intention to proceed in reverse
	• Lane designations and geometry.

Main Event Flow	• HV intends to proceed (forward or backwards). • HV queries video stream providing entities within the 'forward/rear view' scenario application zone. • HV selects suitable entities and requests a video stream. • An entity that is capable of providing a video stream sends it to the HV.
Alternative Event Flow	Not applicable.
Post-Conditions	A video stream is provided to the HV, circumventing the obstructed view from the HV perspective.
Information Requirements	• HV's location. • Surveillance camera's location and vector. • Surveillance camera video stream.

User Story	**Detailed description and specifics**
User Story #1	HV faces an obstacle obstructing its view while on a road, at an intersection, sidewalk, parking lot or driveway. It queries entities in its vicinity capable of providing a video stream that extends the HV's view, making it possible to see around/behind the obstacle.

	One or several CCTV cameras with communication abilities are installed and respond to the query (possibly along with other entities), providing their position, heading vector, available bandwidth, and potentially other values. HV requires a video stream from one or several CCTV cameras. The (one or more) CCTV cameras send their real-time video stream to the HV.
User Story #2	HV faces an obstacle obstructing its view while on a road, at an intersection, sidewalk, parking lot or driveway. It queries entities in its vicinity capable of providing a video stream that extends HV's view, making it possible to see around/behind the obstacle. No CCTV camera is available, but other vehicles respond to the query stating their position, heading angle, velocity, available bandwidth for video stream communication, and possibly other values. HV requires video stream from one or several vehicles. The vehicles send the video stream to the HV.

User Story #1 **(Provision of Video Stream Via CCTV)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	100	The communication range required between cameras and vehicle. For big intersections in metropolitan environments, cameras might still be rather far away, thus more than 100 m may be needed.
Information Requested/Generated	Quality of information/ Information needs	5 Mbps	Video streaming: ~5 Mbps are needed to transmit a progressive high-definition video signal with resolution 1280 x 720, frame-rate 30 Hz, colour depth 8 bit, 24 bit resolution, sub-sampling 4:2:2 and a typical compression of 1:30 (e.g. with H.264).
Service Level Latency	[ms]	50	This value represents the end-to-end communication latency, without any application-layer processing like coding, decoding, etc. This latency should be kept; lower values would enhance the experience for users and provide safety improvements.

Service Level Reliability	%	99	Reliability of 99% at the communication layer for video frames is needed to avoid massive artefacts that may lead to degradation of video quality for assisted driving. The video will support the decision of the driver to perform a certain manoeuvre and should thus be provided in high enough quality to support that.
Velocity	[m/s]	2.8	The cameras are stationary, the velocity of the HV will be slow. If obstructed view is handled before a complete stop, then HV speeds might still be in the range of 10 km/h.
Vehicle Density	[vehicle/km^2]	12000	Obstructed view might happen in dense metropolitan areas with a lot of vehicles around.
Positioning	[m]	2 (3σ)	The position of the HV does not need to be too accurate, as long as it can be determined which camera(s) should provide a video stream to get the most out of the Use Case.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/ Yes/Yes	Interoperability between different OEMs is not needed, since only I2V communication is happening. Regulation and standardisation is needed; a common video format, coding/decoding scheme, etc. should be used by all vehicles and cameras.

User Story #2 **(Provision of Video Stream Via RVs)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	200	The communication range required between HV and other vehicle. Suitable RVs will in most cases be moving towards the HV, so a higher communication range is recommended in order to provide a sufficient safety margin to make use of the RVs detected (notwithstanding where they already passed the spot where a video stream might be helpful for the HV).

Information Requested/Generated	Quality of information/ Information needs	5 Mbps	Video streaming: ~5 Mbps are needed to transmit a progressive high-definition video signal with resolution 1280 x 720, frame-rate 30 Hz, colour depth 8 bit, 24 bit resolution, subsampling 4:2:2 and a typical compression of 1:30 (e.g. with H.264).
Service Level Latency	[ms]	50	This value represents the end-to-end communication latency, without any application-layer processing like coding, decoding, etc. This latency should be kept; lower values would enhance the experience for users and provide safety improvements.
Service Level Reliability	%	99	Reliability of 99% at the communication layer for video frames is needed to avoid massive artefacts that may lead to degradation of video quality for assisted driving. The video will support the decision of the driver to perform a certain manoeuvre and should thus be provided in high enough quality to support that.
Velocity	[m/s]	27.8	The velocity of the HV will be slow. If obstructed view is handled before a complete stop, then velocities of the HV might still be in the range of 10 km/h. The RVs might be driving at normal speed (for all roads except highways), so a maximum expected speed of 100 km/h seems reasonable.
Vehicle Density	[vehicle/km^2]	12000	Obstructed view might happen in dense metropolitan areas with a lot of vehicles around.
Positioning	[m]	1.5 (3σ)	Requirement driven by positioning accuracy for RVs. Here, a lane-level resolution might be needed in order to be able to determine which RVs are most suitable for video stream provision.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability is needed between HV and RVs to understand query, response, and demand for video stream, respectively. Regulation and standardisation is needed, since a common video format,

			coding/decoding scheme, etc. should be used by all vehicles.

5.2.8 Vehicle Decision Assist

Use Case Name	**Vehicle Decision Assist**
Short Description	A host vehicle detects a stationary vehicle in front. It enquires whether this RV is only stopping for a short period of time or if it has broken down or similar, making it necessary to overtake the vehicle. In a more generalised form, a vehicle is able to request various information from a RV, which will then share such information with the HV.
1. RV Waiting for Short Period of Time	• HV approaches a RV on narrow rural road, realises it is stationary. • Due to dense traffic in the opposite direction, it is not possible to overtake the RV easily, so the HV requests information about the RV's likely length of stay. • RV reports that it will continue driving after a short while. • HV receives feedback and decides not to initiate a cooperative overtaking manoeuvre, informing the RV of that decision. After a short while, the RV continues driving, with the HV following behind.
2. RV Broken Down	• HV approaches a RV on narrow rural road, and perceives it as stationary. • Due to dense traffic in the opposite direction, it is not possible to overtake the RV easily, so the HV requests information about the RV's likely length of stay. • RV reports that it is broken down (i.e. mechanical failure). • HV receives feedback and decides to initiate a cooperative overtaking manoeuvre together with cars in the opposite direction (different Use Case), informing the RV of the decision.
3. Bus Having to Wait	• Due to good traffic conditions, a bus arrived at a station ahead of schedule. • The driver thus has to wait at that station before continue along the regular route. • An HV approaches the bus unsure how long it intends to wait. • It sends an enquiry to the bus, asking for the expected duration of stay. • The bus, knowing its schedule, reports the expected time of departure. • The HV receives feedback and adjusts its driving strategy. It may also further provide the information to oncoming traffic.
4. Slow Vehicle on Route	• HV approaches a slow vehicle on a one-lane road. • HV enquires how long the RV will stay on the same route as the HV. • RV shares this information with the HV. • HV can base a decision on whether/where to overtake on the feedback received.

	• HV informs the RV on the driving strategy. • HV may inform oncoming traffic on the route of the event.
Category	Safety, advanced driving assistance.
Road Environment	Urban, rural, highway.
Actors	Host vehicle, remote vehicle.
Vehicle Roles	Host vehicle, remote vehicle.
Road/Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	Assist a vehicle in deciding whether it should overtake a stationary vehicle it detects in front, and enable vehicles to exchange arbitrary information.
Needs	Not applicable.
Constraints/ Presumptions	All participating vehicles need to be equipped with communication abilities.
Geographic Scope	Global.
Use Case diagram	Not applicable.
Sequence diagram	Not applicable.
Further Illustrations	Not applicable.
Pre-Conditions	• HV needs to be able to request information from other vehicles. • It might be necessary to consider privacy, depending on the information requested.
Pre-Conditions RVs	• RV needs to be able to (roughly) predict how long it expects to remain stationary, or at least be able to interact with its driver to inform them about the expected length of stay. • RV needs to be able to process the information requests received from the HV.
Main Event Flow	• HV detects a stationary vehicle in front, e.g. via sensors, communication, etc. • HV sends enquiry to the vehicle about its expected duration of stay. • RV sends report to the HV on the expected duration, along with other potential information such as whether an accident happened, if help is needed, etc. • HV accommodates the answer in its driving strategy, e.g. in order to determine whether or not to overtake. • HV potentially informs other vehicles about the RV and its expected duration of stay.
Alternative Event Flow	• HV detects a vehicle in front, e.g. via sensors, communication, etc. • HV sends an information enquiry to the RV • RV sends back the requested information - to the extent possible • HV accommodates the answer in its driving strategy

	• HV potentially informs other vehicles about the RV.
Post-Conditions	• HV is informed about the RV's status • Other vehicles are able to receive information about the RV.
Information Requirements	• RV's duration of stay/other information • Optionally, a vehicle status report from the RV (broken down vs. normal operation) • Potentially other information (flexible approach).

User Story #1 (RV Waiting for a Short Period of Time) **User Story #2 (RV Broken Down)** **User Story #3 (Bus Having to Wait)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	500	500 m potentially allows the vehicles to exchange information, derive a decision, and coordinate an overtake manoeuvre together with the oncoming traffic.
Information Requested/Generated	Quality of information/ Information needs	1000 bytes	For stationary vehicle decision assist, not that much information is likely to be needed (duration of stay, accident, need for help, etc.).
Service Level Latency	[ms]	100	Stationary vehicle decision assists is not a time-critical Use Case, therefore 100 ms should be enough.
Service Level Reliability	%	99.9	In general, there is some requirements related to reliability. However, overly strict requirements might not be necessary for this group of Use Cases.
Velocity	[m/s]	69.4	A worst-case scenario for this Use Case as foreseen might be a stationary vehicle (v=0) on a highway, where HV's velocity v=250 km/h.
Vehicle Density	[vehicle/km^2]	1000	Downscaled value of 12,000 vehicles that is used as the maximum density estimated in a dense urban grid because in the event of a total traffic jam, the Use Case stationary vehicle decision assist is not applicable. This number is calculated for 1 lane in each direction with 20 m inter-vehicle distance.

Positioning	[m]	1.5 (3σ)	Lane-level accuracy would be helpful. Higher accuracy should not be needed.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability is needed. Regulatory measures would improve implementation speed. Standardisation is needed especially for the way information is requested and described.

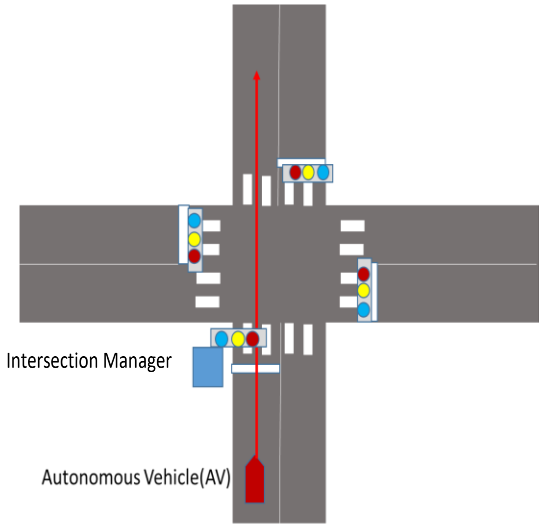
User Story #4 (Slow Vehicle on Route)			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	500	500 m potentially allows vehicles to exchange information, derive a decision, and potentially coordinate an overtake manoeuvre together with the oncoming traffic.
Information Requested/Generated	Quality of information/ Information needs	Few bytes to few MB	Depending on the amount and nature of information exchanged, quite a range might be assumed here.
Service Level Latency	[ms]	100	In most foreseen situations, this Use Case will not be applied in a time-critical way. One criterion is that, for arbitrary information, the RV may not be able to process/understand the request. Here, it would be too great a risk to perform such requests in time-critical emergency situations.
Service Level Reliability	%	99.9	In general, there is some requirements related to reliability. However, overly strict requirements might not be necessary for this group of Use Cases.
Velocity	[m/s]	69.4	The worst-case scenario for this Use Case, as foreseen, might be a stationary vehicle (v=0) on a highway, where the HV's velocity v= 50 km/h.
Vehicle Density	[vehicle/km^2]	10,000	The worst-case scenario could be every vehicle in a dense urban grid requesta some kind of information from another vehicle.

Positioning	[m]	1.5 (3σ)	Lane-level accuracy would be helpful. Higher accuracy should not be needed.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability is needed. Regulatory measures would improve implementation speed. Standardisation is needed especially for the way arbitrary information is requested and described.

5.4 Autonomous Driving

5.4.1 Automated Intersection Crossing

Use Case Name	Automated Intersection Crossing
User Story	An autonomous vehicle goes through the intersection while respecting the signal traffic signal.
Category	Autonomous driving.
Road Environment	Intersection.
Short Description	An autonomous vehicle goes through an intersection with a set of traffic lights. AV goes through or stops taking signal timing into account. When stopping at the intersection, the AV can readjust its position.
Actors	Host vehicle, traffic lights.
Vehicle Roles	Host vehicle goes through the intersection automatically.
Roadside Infrastructure Roles	Traffic lights (intersection manager) control traffic flow at intersections.
Other Actors' Roles	Not applicable.
Goal	Go through an intersection in automatic driving mode.
Needs	Host vehicle needs to know the roads, lane designations and geometry. It also needs to know the phase and timing of the traffic lights at the intersection.
Constraints/ Presumptions	Host vehicle can drive automatically using the roads, lane designations, geometry and the phase and timing of traffic lights at the intersection.
Geographic Scope	Intersection.
Illustrations	

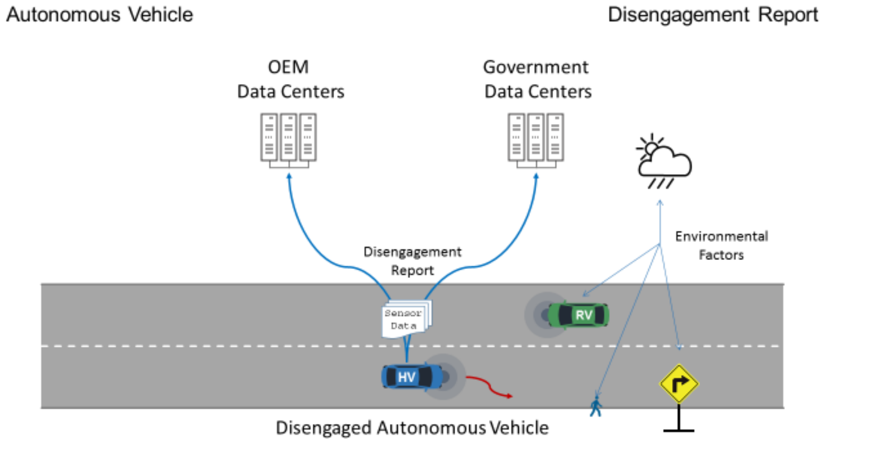
	 Note: In this scenario the intersection manager is locally placed, and can be centrally located as well.
Pre-Conditions	HV is in the scenario's application zone.
Main Event Flow	• The intersection manager sends to the HV the roads, lane designations, geometry and the phase and timing of traffic lights at the intersection. • HV receives the roads, lane designations, geometry and the phase and timing of traffic lights at the intersection, and the HV creates its own driving scenario using the information received. • HV goes through or stops taking signal timing into account; it can stop at the correct position using the roads, lane designations and geometry.
Alternative Event Flow	Not applicable.
Post-Conditions	HV passes through the intersection and continues automated driving.
Information Requirements	• HV's location and dynamics. • Lane designations and geometry of intersection. • Road conditions. • Phase and timing of traffic lights.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	500	With a relative speed of 160 km/h, in order to provide time-to-collision (TTC) of 10 sec. plus headway time of 2 sec. around 500 m of communication range is needed.

Information Requested/Generated	Quality of information/ Information needs	300-450 bytes per vehicle 100 bytes for traffic light information 1000 bytes for intersection geometry information 400 bytes for intersection manager data	• 300-450 bytes per awareness message (vehicles) e.g. CAM, BSM (≤ 10 Hz) • Traffic light information e.g. SPaT: 100 bytes (1 Hz). • Intersection geometry information e.g. MAP: 1000 bytes in 1 sec. • Intersection manager data: 400 bytes (e.g. trajectory information/planned velocity/vehicle).
Service Level Latency	[ms]	10	Coordination and intersection manager messages might be issued within a short period of time.
Service Level Reliability	%	99.9999	High reliability is needed due to safety reasons.
Velocity	[m/s]	Urban: 19.4 Rural: 33.3	Different maximum speeds for the road environment where this Use Case could be realised or put into effect.
Vehicle Density	[vehicle/km^2]	3200	Assumes that at one intersection (urban environment) there are up to 8 groups of 10 vehicles each (80 vehicles). Further assuming that there are up to 40 intersections per km^2 (e.g. in Manhattan), the result is 3200 vehicles/km^2 as an upper bound. Present VRUs per km^2: ~10000 Concerned VRUs are the ones near streets, not counting workers in offices or the like. However, to calculate the total network load, etc., all VRUs in the given area have to be considered.
Positioning	[m]	0.15 (3σ)	For autonomous vehicle control.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability is necessary between OEMs and infrastructure elements. Regulation is needed because authorities may need to specify the maximum speed, minimum accuracy, etc.

5.4.2 Autonomous Vehicle Disengagement Report

Use Case Name	**Autonomous Vehicle Disengagement Report**
User Story	When an autonomous HV virtual driver system disengages, it submits a disengagement report containing a time-windowed recording of vehicle systems data, rich sensory information and dynamic environmental conditions to OEM and government data centres.
Category	Autonomous driving.
Road Environment	Urban, rural, highway.
Short Description	Host vehicle sends a disengagement report to OEM and government data centres.
Actors	Host vehicle and remote vehicle.
Vehicle Roles	• HV represents the autonomous vehicle that is sending the report. • RVs provide dynamic environmental input to the autonomous vehicle.
Roadside Infrastructure Roles	Signs and traffic signals provide dynamic environmental input to the autonomous vehicle.
Application Server Roles	Not applicable.
Other Actors' Roles	• OEM and government data centres are receiving the reports. • Vulnerable road users provide dynamic environmental input to the autonomous vehicle.
Goal	Send disengagement reports to OEM and government data centres.
Needs	HV needs to send a disengagement report containing a time-windowed recording of vehicle systems data, rich sensory information and dynamic environmental conditions to OEM and government data centres.
Constraints/ Presumptions	• Information from RVs and other actors includes typical data in support of other safety applications. • Any government reporting should follow recommended standards if mandated.
Geographic Scope	Global.

Illustrations	
Pre-Conditions	The 'disengagement report' scenario is enacted when the autonomous HV's virtual driver system is faced with an unmanageable situation and decides to disengage.

Main Event Flow	• If the 'disengagement report' scenario is enacted
	    ○ HV notifies nearby actors of the event and need to capture data
	    ○ HV captures its own system data
	    ○ HV captures its own sensory data
	    ○ HV sends its own event data to OEM data centres and government data centres where required
	    ○ Nearby actors capture relevant data and send it to the HV
	        ▪ Relevant surveillance cameras capture a time-windowed recording
	        ▪ RVs capture their location and dynamics
	        ▪ VRUs capture their location and dynamics
	        ▪ Traffic signals capture timing and phase information
	
	HV sends a disengagement report to OEM data centres and government data centres where required.

Post-Conditions	HV sent a disengagement to OEM data centres and government data centres where required.

Information Requirements	• HV's disengagement report including a captured time window of
	    ○ HV system data
	    ○ HV sensory data including cameras, RADAR, LIDAR, etc.
	    ○ Environmental data including
	        ▪ Position and dynamics of RVs
	        ▪ Position and dynamics of vulnerable road users
	        ▪ Position, nature and state of traffic signals, signs, etc.
	        ▪ Surveillance cameras
	        ▪ Weather and road conditions
	• Connectivity status.

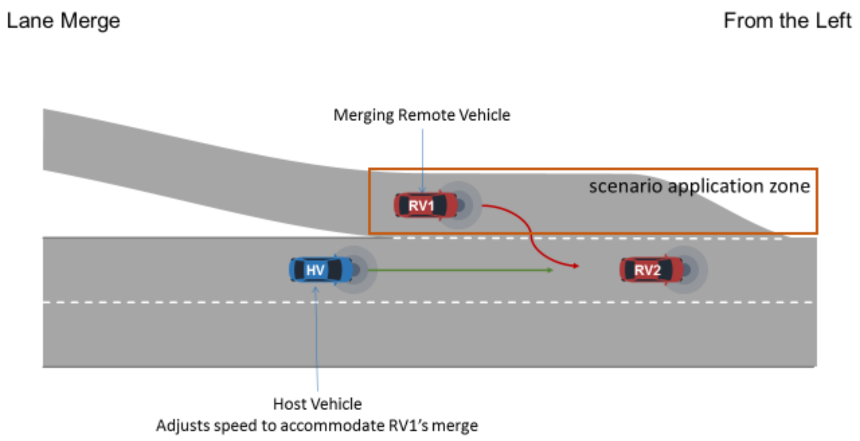
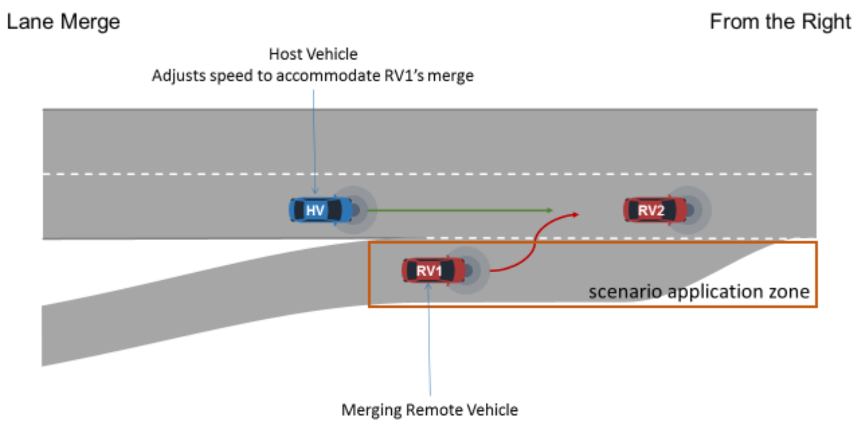
User Story	**Detailed description and specifics**

User Story #1	An autonomous vehicle is stopped in the middle of a city street due to unanticipated roadworks blocking a lane ahead. Human driver assistance requested.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Needs to reach a cloud centre.
Information Requested/Generated	Quality of information/ Information needs	Detailed sensor report immediately before the disengagement	Collect detailed sensor data 15 sec. prior to disengagement. The estimate is on the order of 2 GB. Assuming 10 min. transmission time result in 26.7 Mbps.
Service Level Latency	[ms]	Est. 10 minutes	Not highly time critical.
Service Level Reliability	%	High/99.99	A high degree of reliability is needed for data transfer.
Velocity	[m/s]	69.4	The maximum speed considered on a highway, although speed SLR is not critical for this Use Case.
Vehicle Density	[vehicle/km^2]	12000	Maximum assumed density in an urban situation.
Positioning	[m]	1.5 (3σ)	Required for accurate understanding where the disengagement occurred.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Interoperability with the government cloud would be needed, but interoperability is not required between vehicles.

5.4.3 Cooperative Lane Merge

Use Case Name	**Cooperative Lane Merge**
User story	A host vehicle accommodates a remote vehicle that is merging into the HV's traffic lane.
Category	Autonomous driving.
Road Environment	Urban, rural, highway.
Short Description	A host vehicle accommodates a remote vehicle travelling ahead in an adjacent lane that is merging with the HV's traffic lane.
Actors	• Remote vehicle 1 (RV1). • Remote vehicle 2 (RV2). • Host vehicle (HV).

Vehicle Roles	• RV1 represents the vehicle merging into the HV's traffic lane. • RV2 represents a lead vehicle in the HV's traffic lane. • HV represents the vehicle accommodating RV1's manoeuvre.
Road/Roadside Infrastructure	Roads are defined by their lane designations and geometry.
Other Actors' Roles	No other actors have been considered.
Goal	Enable safe cooperative lane-merge manoeuvres.
Needs	• HV needs to be aware of RV1's merge into HV's traffic lane. • HV needs to know RV2's location and dynamics. • HV needs to know the roads, lane designations and geometry. • RV1 needs to know if the HV intends to accommodate RV1's manoeuvre.
Constraints/ Presumptions	• The 'from the left' scenario application zone is defined by the geometry of an adjacent merging lane to the immediate left of the HV starting from the position of the HV and ending at the end of the merging lane. • The 'from the left' scenario application zone is defined by the geometry of an adjacent merging lane to the immediate left of the HV starting from the position of the HV and ending at the end of the merging lane.
Geographic Scope	Everywhere.
Illustrations	

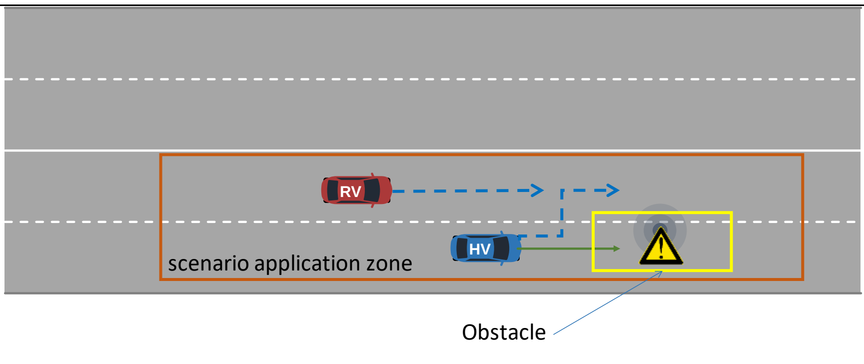
Pre-Conditions	RV1 is in the scenario's application zone.
Main Event Flow	• HV receives RV1's intention to apply a lane-merging manoeuvre, providing location, speed and manoeuvre information. • If there is not a lead vehicle RV2 then o HV uses RV1's location and dynamics and the length of the merge to adjust the speed of the HV, such that at the end of the manoeuvre, the HV is positioned in a safe following distance from RV1 o RV1 is made aware of the HV's intention to accommodate the manoeuvre. It adapts accordingly (if needed) its speed and notifies the HV for acceptance before initiating the manoeuvre • If there is a lead vehicle RV2 then o HV uses RV1's location and dynamics, RV2's location and dynamics and the length of the merge to adjust the speed of the HV, such that at the end of the manoeuvre, the HV is positioned a safe following distance from RV1 and RV1 is positioned a safe following distance from RV2 • RV1 is made aware of HV's intention to accommodate the manoeuvre. It adapts accordingly (if needed) its speed and notifies the HV for acceptance before initiating the manoeuvre.
Alternative Flow	• HV receives RV1's intention to apply a lane-merging manoeuvre, providing location, speed and manoeuvre information. • HV uses RV1's location and dynamics, adjacent lane traffic conditions and decides (i.e. HV) to change lane, such that at the end of HV's manoeuvre, the HV allows RV1 to merge. • RV1 is made aware of HV's intention to accommodate the manoeuvre, by changing its lane. RV1 notifies the HV for the acceptance (or not) and initiation of its manoeuvre.
Post-Conditions	After the merge, the HV is positioned a safe following distance from RV1 and RV1 is positioned a safe following distance from any lead RV2.
Information Requirements	• RV1's location and dynamics. • RV2's location and dynamics. • HV's location and dynamics. • Lane designations and geometry. • Road conditions.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	150	Assuming that a vehicle (i.e. HV), including inter-vehicle gap is 15 m, and 10 vehicles are involved in the cooperative manoeuvres, the resulting range is 150 m.

Information Requested/Generated	Quality of information/ Information needs	48 Kbps	Rate for continuous stream of messages after initial message exchange (cf. UC description).
Service Level Latency	[ms]	10	Very low latency is needed for messages that should be exchanged fast (e.g. share of intents, RV notification), since it is directly related with vehicles' safety and ability to avoid collisions where even a few centimetres could be important.
Service Level Reliability	%	95	In the continuous stream of messages, some could be lost, therefore the Service Level Reliability should be approximately 99.9%, as stated in the user case description. For message retransmission, then the probability of losing both copies of one message is 0.05*0.05=0.0025, equivalent to a Service Level Reliability of 99.75%, which is good enough.
Velocity	[m/s]	Urban: 19.4 Rural: 33.3 Highway: 69.4	Different maximum speeds for corresponding road environments where this Use Case could be implemented.
Vehicle Density	[vehicle/km^2]	4500 (Highway) 9000 (Rural) 12000 (Urban)	Maximum density of vehicles considered in the different road environments where this Use Case could be implemented.
Positioning	[m]	0.2 (3σ)	Very high position accuracy is needed, since the goal is to avoid collision among vehicles and/or with an object.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes / Yes / Yes	This Use Case is possible for different brands. Regulatory oversight for safety related questions is needed. Standardisation on the application layer (message set and flow control).

5.4.4 Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations

Use Case Name	**Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations**
User Story	An autonomous vehicle identifies a dangerous situation (e.g. collision with a moving object) and undertakes to coordinate with neighbouring AVs in order to jointly decide and perform their manoeuvres.

Category	Autonomous driving.
Road Environment	Intersection, urban, rural, highway.
Short Description	An obstacle is detected by an autonomous vehicle in its lane and a manoeuvre is needed to avoid a crash with the obstacle e.g. sudden lane change. However, this could result in an accident with a neighbouring or approaching AVs in the adjacent lane. The emergency manoeuvre, together with the actions (e.g. emergency braking, manoeuvre) of neighbouring vehicles are agreed and planned in a cooperative manner. The cooperation among AVs avoids the dangerous situation, reduces the risk of a collision with adjacent AVs in an emergency manoeuvre, and thus improves safety.
Actors	Vehicle.
Vehicle Roles	There are two roles of AVs involved in this Use Case: • Host vehicle. • Remote vehicle.
Road/Roadside Infrastructure	Not a necessary role for the specific user story.
Other Actors' Roles	No other necessary roles envisaged in this specific user story.
Goal	Eliminate accidents during unforeseen situations by enabling quick coordination between vehicles.
Needs	To enable vehicles to exchange information about intended manoeuvres and agree on planned trajectories in a cooperative manner.
Constraints/ Presumptions	The HV and RVs are AVs and equipped to share messages conveying precise location, speed, acceleration, trajectories and sensor data.
Geographic Scope	Everywhere.
Illustrations	
Pre-Conditions	RV is following the HV in the adjacent lane.
Main Event Flow	• The HV detects an obstacle, using information received from sensors or cameras on the HV and identifies the need to execute an emergency manoeuvre to avoid a collision. • The HV, taking into account the distance from the obstacle, road conditions (if available) and the position of other RVs, shares its intention (e.g. trajectory) to avoid the collision with the detected obstacle.

	• The RV(s), based on current status and location and considering traffic and road conditions, checks if the HV's shared intention can be executed without creating any further risks/collisions between the corresponding RV and the HV due to the emergency manoeuvre
	  ○ If an adaptation of RV's driving behaviour is needed to allow the HV to apply its emergency manoeuvre in a safe manner, then the RV informs the HV about its updated intention and/or acceleration/braking, etc.
	  ○ Or the RV replies to the HV by providing its own intentions
	• The HV checks whether it needs to adapt its original intention taking into account the RVs' response, and notifies the RV about any updated intentions.
	• Lateral and longitudinal controls are applied simultaneously (based on agreed intentions) by the HV and RVs until the manoeuvres are completed.

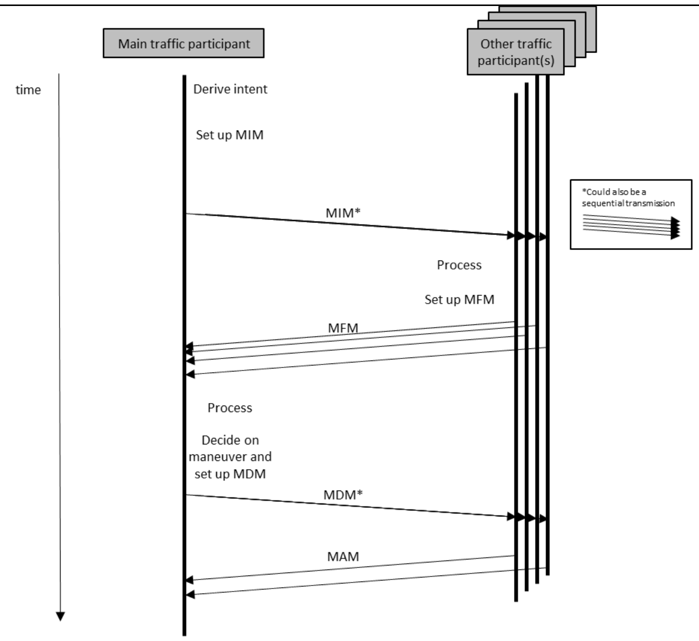
Alternative Event Flow	Not applicable.
Post-Conditions	After the completion of the agreed manoeuvres and the HV has avoided colliding with the detected obstacle, the AVs (HV, RV) drive safely towards their defined destination.
Information Requirements	• Vehicles' location, speed information. • Vehicles' trajectory. • Driving intention (brake, accelerate). • Traffic conditions. • Road conditions.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	150	Assuming that a vehicle (i.e. HV), including inter-vehicle gap is 15 m, and 10 vehicles are involved in the cooperative manoeuvres, the resulting range is 150 m.
Information Requested/Generated	Quality of information/ Information needs	48 Kbps	Rate for continuous stream of messages after initial message exchange (cf. UC description).
Service Level Latency	[ms]	10	Very low latency is needed for messages that should be exchanged fast (e.g. share of intents, RV notification), since it is directly related with vehicles' safety and ability to

			avoid collisions where even a few centimetres could be important.
Service Level Reliability	%	95	In the continuous stream of messages, some could be lost, therefore the Service Level Reliability should be approximately 99.9%, as stated in the user case description. For message retransmission, then the probability of losing both copies of one message is 0.05*0.05=0.0025, equivalent to an Service Level Reliability of 99.75%, which is good enough.
Velocity	[m/s]	Urban: 19.4 Rural: 33.3 Highway: 69.4	Different maximum speeds for corresponding road environments where this Use Case could be implemented.
Vehicle Density	[vehicle/km^2]	4500 (Highway) 9000 (Rural) 12000 (Urban)	Maximum density of vehicles considered in the different road environments where this Use Case could be implemented.
Positioning	[m]	0.2 (3σ)	Very high position accuracy is needed, since the goal is to avoid collision among vehicles and/or with an object.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	This Use Case is possible for different brands. Regulatory oversight for safety related questions is needed. Standardisation on the application layer (message set and flow control).

5.4.5 Coordinated, Cooperative Driving Manoeuvre

Use Case Name	**Coordinated, Cooperative Driving Manoeuvre**
Category	Safety, convenience, advanced driving assistance.
Road Environment	Intersection, urban, rural, highway.
Short Description	• A main traffic participant wants to perform a certain action (e.g. lane change, exit highway, U-turn, etc.). • Participant shares this intention with other traffic participants potentially involved in the manoeuvre. • The traffic participants indicate to the main traffic participant whether they support or plan to decline the planned manoeuvre. • The main traffic participant informs a superset of the traffic participants informed whether it plans to perform the manoeuvre. Note: Assumes that every vehicle, on average, might plan on performing a manoeuvre using this Use Case as a main traffic participant once every

	1-10 seconds in urban scenarios. On highways with less traffic, an interval of approximately once every 1-20 seconds might be enough.
Actors	Vehicles.
Vehicle Roles	Host vehicle, remote vehicles might play the role of one or more traffic participants.
Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	Vulnerable road users, such as cyclists, pedestrians, might play the role of one or more traffic participants.
Goal	The main traffic participant is able to evaluate whether a certain manoeuvre can be performed. Other traffic participants are informed about manoeuvres planned by the main traffic participant.
Needs	The main traffic participant needs to receive feedback messages from other traffic participants.
Constraints/ Presumptions	• The main traffic participant needs to be equipped with the means to inform other traffic participants about planned manoeuvres. • Other traffic participants need to be able to signal confirmation/support/approval or denial/rejection of the planned manoeuvre. • The main traffic participant needs to be able to process feedback received and needs to be able to inform surrounding traffic participants about the final decision regarding whether the manoeuvre will be performed or not.
Geographic Scope	Global.
Illustrations	
Pre-Conditions	The main traffic participant wants to perform a manoeuvre involving surrounding traffic participants.

Main Event Flow	• The main traffic participant evaluates at least the following aspects and sets up a MIM, accordingly o Identifier: in order to be able to relate MIM to the car that sent it, e.g. based on position o Manoeuvre: type of manoeuvre the main traffic participant wants to perform, e.g. lane change, driving around obstacle and thus into neighbouring lane without lane change, cross a road, turn at an intersection, etc. o Urgency: desired time until main traffic participant wants to start the manoeuvre o Criticality: an indicator on the consequences of not performing the manoeuvre would have for the vehicle (e.g. missing a slip road when not changing a lane, etc.) o Feedback: the type of feedback the main traffic participant is expecting (e.g. support/reject, which variant of a manoeuvre is preferred, additional information, etc.) o Message ID: a random number with enough digits, combined with the manoeuvre type, to provide a unique identifier for all manoeuvres performed at the same time with overlapping application region • The main traffic participant sends the MIM to other traffic participants. • Other traffic participants receive the MIM and process information given within. • After processing, they set up a MFM covering at least the following aspects o Relevant message ID: the message ID received that the current response is referring to o Identifier: in order to be able to later relate MFM to the car that sent it, e.g. based on position o Manoeuvre type: the manoeuvre in question o Support/Rejection: general assessment of one's own involvement in the manoeuvre o Further feedback: relating to the feedback type requested by the main traffic participant o Time horizon: earliest and latest time within which the respective traffic participant would be willing to participate, in the event of supporting the manoeuvre • The MFM is sent back to the main traffic participant, and possibly other traffic participants. • The main traffic participant receives MFMs from surrounding traffic participants and processes them. Based on this, a MDM is set up, covering at least o Relevant message ID: the message ID the current MFM is referring to o Identifier: the identifier also used in the MIM o Manoeuvre decision: whether or not main traffic participant plans to perform the manoeuvre o Starting time: when the main traffic participant plans to initiate the manoeuvre • The MDM is sent to other traffic participants to inform them.

	• In the event the MDM contains the decision to perform the manoeuvre, the participating vehicles send a MAM in order to ensure that all involved parties have received and agreed on the manoeuvre to be taken. This MAM covers at least o Relevant message ID: the message ID the current MAM is referring to o Identifier: the identifier used in MIM and MFM o ACK: field indicating decision to comply with the HV's decision
Post-Conditions	In the event of a decision to perform the manoeuvre, the main traffic participant initiates the manoeuvre at the time indicated in the MDM. Other vehicles take appropriate actions (possibly before the initiation time instant of the main traffic participant).[1] In the event of a decision not to perform the manoeuvre, traffic flows as before, without performing the manoeuvre. Actors might decide to attempt similar/alternative manoeuvres.
Information Requirements	None.[2]
Use Case Name	Coordinated, cooperative driving manoeuvre.
Category	Safety, convenience, advanced driving assistance.
Road Environment	Intersection, urban, rural, highway.

In the following, three different possible application scenarios are described where Coordinated Cooperative Driving Manoeuvres are enabled via the message exchanges outlined above.

User Story	**Coordinated, Cooperative Driving Manoeuvre**
Cooperative Lane Change	The main traffic participant is a host vehicle. It wants to perform a lane change, but there are remote vehicles in the lane that the HV wants to move into. Therefore, it issues a MIM supporting a lane change. RV1 right next to the HV and RV2 behind it both send MFMs containing rejections, but RV3 behind RV2 sends affirmative feedback. After processing the three feedback messages, the HV sends an MDM confirmation including a time instant far enough in the future to give RV1 and RV2 enough time to overtake HV. RV3, after sending a MAM, might already slow down to make room for the HV which then changes lane in front of RV3.
Pedestrian Crossing Road	A pedestrian wants to cross a road with broken traffic lights. His/her mobile device sends out a MIM indicating the intention to cross the road. A vehicle approaching the road sends a supportive MFM. After his/her phone sends an affirmative MDM and he/she receives the respective MAM, the pedestrian starts crossing the road, knowing that the vehicle will decelerate, if necessary, in order not to hit him/her.

[1] This Use Case assumes that appropriate measures are in place to identify and punish misbehaviour (never cooperating, performing manoeuvres without consent of other traffic participants, etc.), for example by revoking a traffic participant's ability to initiate manoeuvres. How such measures could look is not treated in this Use Case description.

[2] No information like car sensor data, positions, or the like is required. Of course, the information stated in the event flow is required to be exchanged.

Road Blockage	One lane of a rural road is blocked by a traffic accident. Traffic heading in the other direction prevents blocked vehicles from driving around the obstacle. A HV approaching the obstacle sends a MIM indicating it wants to drive around the blockage. While some vehicles reject this request (sending respective MFMs), a relatively small vehicle sends a supportive MFM. It drives to the outermost part of the lane or stops in front of the obstacle, making enough room for the blocked HV to drive around it. The HV sends a MDM indicating that it will drive around the obstacle when the small vehicle is near enough. The small vehicle sends a MAM to acknowledge participation.

Note: The SLRs mentioned in this Use Case are illustrative but concrete examples incorporating the Coordinated, Cooperative Driving Manoeuvres Use Case. Individual SLRs will have to be developed for each further Use Case in the future.

User Story #1 (Cooperative Lane Change)			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	500	For a lane change, 500 m of range would make for a time window of $t = \frac{s_{range}}{v_{rel}} = \frac{500\ m}{150\ km/h} * 3.6\ {}^{s}/_{h} = 12\ s$ in the event relative velocity is roughly 150 km/h, this should give enough time for cooperation.
Information Requested/Generated	Quality of information/ Information needs	Manoeuvre description, time horizons, and respective intentions of participants Intent: 5-10 kB Feedback: 5-10 kB Decision: 5-10 kB Ack: 200-500 bytes → max. 50 kB	As described in the main event flow of this Use Case, the data needed to be exchanged might encompass trajectories and planned positions. Data rate requirements in the urban environment (assuming a communication range of 100 m) with 314 vehicles in communication range and average sending frequency of 50 kB every 5 seconds. → data rate within communication range = 24 Mbps Data rate requirements in highway environment (communication range = 500 m) with 7850 vehicles in communication range and average sending frequency of 50 kB every 10 seconds. → data rate within communication range = 64 Mbps
Service Level Latency	[ms]	4 * 40	Since the lane change described here is not an overly critical Use Case scenario, 4 times 40 ms should leave enough time for processing each car.

Service Level Reliability	%	99.9	In order to be able to plan manoeuvres, all messages should be received, reliably.
Velocity	[m/s]	41.67 (=150 km/h)	Since this user story only deals with relative velocities of vehicles driving in the same direction.
Vehicle Density	[vehicle/km^2]	12000 for urban 4500 for highways	Use Case applicable to highly congested urban areas. NB: In general, this Use Case should be applicable to all environments and driving situations. However, in high traffic scenarios, generating even more traffic by applying this Use Case should be avoided.
Positioning	[m]	1.5 (3σ)	In order to resolve cars with lane accuracy.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability across multiple OEMs is required. Regulations are needed in order to derive limits for parameters involved. A common, internationally standardised protocol is needed.

User Story #2 **(Pedestrian Crossing)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	300	Range of 300 m sufficient to leave $t = \frac{s_{range}}{v_{rel}} = \frac{500\ m}{120\ km/h} * 3.6\ {}^{s}/_{h} = 15\ s$ of reaction time, which should be enough for a pedestrian crossing the road.
Information Requested/Generated	Quality of information/ Information needs	Manoeuvre description, time horizons, and respective intentions	As described in the main event flow of this Use Case the data needed to be exchanged might encompass trajectories and planned positions. Data rate requirements in the urban environment (assuming communication range of 100 m) with 314 vehicles in communication range and

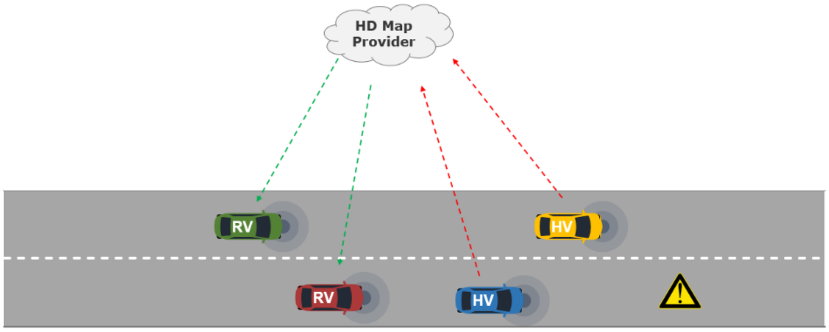
		of participants Intent: 5-10 kB Feedback: 5-10 kB Decision: 5-10 kB Ack: 200-500 bytes →max. 50 kB	average sending frequency of 50kB every 5 seconds. → data rate within comm. range = 24 Mbps Data rate requirements in highway environment (communication range = 500 m) with 7850 vehicles in communication range and average sending frequency of 50 kB every 10 seconds. → data rate within comm. range = 64 Mbps
Service Level Latency	[ms]	4 * 20	Due to • low velocity of VRU when crossing the road • probably smaller processing power on VRU's UE communication latency should still be kept to a rather small value in order to give enough time for processing and for the VRU to cross the road.
Service Level Reliability	%	99.9	In order to be able to plan manoeuvres, all messages should be received, reliably.
Velocity	[m/s]	33.3 (=120 km/h)	Expected relative velocity between pedestrian and vehicle driving on urban road.
Vehicle Density	[vehicle/km^2]	12,000	This number reflects the maximum number of vehicles present within 1 km^2 of the urban road grid. The number of pedestrians trying to cross the streets has not been included in this consideration in order to be consistent with other SLRs mentioned in this Technical Report.
Positioning	[m]	1.0 (3σ)	In order to resolve cars with lane accuracy and correctly identify pedestrians along the road.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability across multiple vehicle OEMs and UE manufacturers is required. Regulations are needed in order to derive limits for parameters involved. A common, internationally standardised protocol is needed.

User Story #3 (Road Blockage)			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	300	For a lane change, 500 m of range would make for a time window of $t = \frac{s_{range}}{v_{rel}} = \frac{500\ m}{150\ km/h} * 3.6\ {}^{s}/_{h} = 12\ s$ in the event relative velocity is roughly 150 km/h, this should give enough time for cooperation.
Information Requested/Generated	Quality of information/ Information needs	Manoeuvre description, time horizons, and respective intentions of participants Intent: 5-10 kB Feedback: 5-10 kB Decision: 5-10 kB Ack: 200-500 bytes →max. 50 kB	As described in the main event flow of this Use Case the data needed to be exchanged might encompass trajectories and planned positions. Data rate requirements in urban environment (assuming communication range of 100 m) with 314 vehicles in communication range and average sending frequency of 50 kB every 5 seconds. → data rate within comm. range = 24 Mbps Data rate requirements in highway environment (communication range = 500 m) with 7850 vehicles in communication range and average sending frequency of 50 kB every 10 seconds. → data rate within comm. range = 64 Mbps
Service Level Latency	[ms]	4 * 20	Due to the acceleration needed when driving around the obstacle (starting from stationary position/waiting), the communication latency should be kept rather low.
Service Level Reliability	%	99.9	In order to be able to plan manoeuvres, all messages should be received, reliably.
Velocity	[m/s]	33.3 (=120 km/h)	This Use Case should work under all circumstances and for all types of manoeuvres that build on it.
Vehicle Density	[vehicle/km^2]	400	Assume ~20 vehicles involved in this Use Case (1 at the head of the queue of waiting vehicles, 19 lined up the different direction), then up to 20 obstacles could block rural roads within 1 km2 at the same

			time, as might be the case after a storm, for example.
Positioning	[m]	1.5 (3σ)	In order to resolve cars with lane accuracy.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability across multiple OEMs is required. Regulations are needed in order to derive limits for parameters involved. A common, internationally standardised protocol is needed.

5.4.6 High-Definition Map Collecting and Sharing

Use Case Name	**HD Map Collecting and Sharing**
User Story	For vehicles to acquire an accurate HD map updated in real-time.
Category	Autonomous driving.
Road Environment	Intersection, urban, rural, highway.
Short Description	Vehicles equipped with LIDAR or other HD sensors can collect environment data around themselves, and share the information with a HD map provider (e.g. cloud server). The HD map provider analyses the information collected and merges or combines it to build a regional HD map. This helps to build HD maps that are dynamically updated and more accurate.
Actors	Host vehicle, remote vehicle.
Vehicle Roles	• HVs collect information about their surroundings using their own sensor devices, and share the information with a HD map provider. • RV receives the HD map; each HV can also play the role as a RV.
Road/Roadside Infrastructure Roles	Can provide sensor data or other information useful for the building of a HD map.
Other Actors' Roles	HD map provider collects sensor information from HVs and optionally also from road and roadside infrastructure in order to build the HD map.
Goal	The vehicles receive (or build) fresh map information in a timely fashion to complete a HD map.
Needs	To provide safety and optimal route selection for semi- and fully automated driving by exploiting the availability data gathered from sensor information shared by other vehicles.
Constraints/ Presumptions	The HV and RV can establish an authenticated and secure communication channel between each other or with the HD map provider.
Geographic Scope	Global.

Illustrations	
Pre-Conditions	The vehicles can make optimal driving decisions based on an up-to-date, precise, and reliable vision of the environment. The HVs are equipped with sensors and they can share sensor information. The HD map provider can collect (and merge) sensor information from different sources to build the HD map in a fast and reliable manner.
Main Event Flow	• HVs gather environment information from their own sensors. • HVs provide sensor information to the HD map provider. • The HD map provider analyses and merges/combines the sensor data to build a unified (more complete) HD map, and refreshes the map in real time. • The map provider provides the HD map. • RVs receive the real-time HD map.
Alternate Event Flow	Not applicable.
Post-Conditions	RV can make an optimal driving decision based on an up-to-date, precise, and reliable vision of the environment using the more accurate, real-time HD map as well.
Information Requirements	• Car sensor data (RADAR, LIDAR, etc.). • Road conditions. • Car status (e.g. location, dynamics, etc.). • Events detected by vehicles.

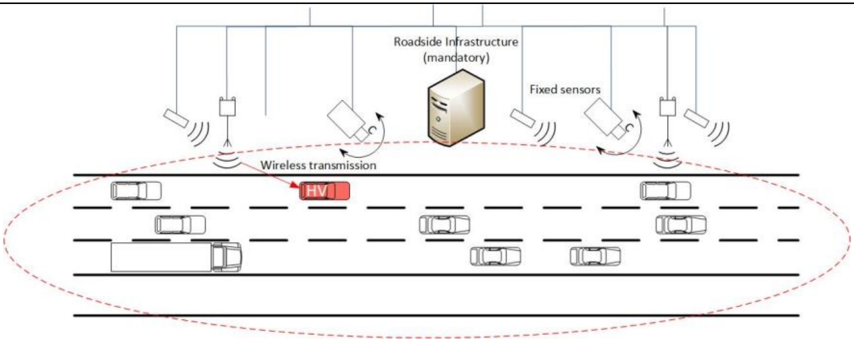
User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	City: >500 Highway: >1000	In a city, 500 m range is about two blocks around the vehicle. An AV can depend on at least two blocks of dynamic HD map use for trajectory planning and avoiding collisions/congestions. While on the highway, because of higher speeds and less surrounding road information than in the city, 1000 m will be a suitable range.
Information Requested/Generated	Quality of information/	UL: Case 1: 47 Mbps	Case 1: Unprocessed but compressed sensor data are provided from a HV to the HD map provider. 47 Mbps is derived from:

	Information needs	Case 2: 4 Mbps DL: 16 Mbps	H.265/ HEVC HD camera ~8 Mbps + LIDAR ~35 Mbps + other sensor data. Case 2: Processed sensor data (interpreted objects) are provided from the HV to the HD map provider. We can assume 1 kB/Object/100 ms. So if we assume 50 objects per HV end up with 4 Mbps. HD maps of 500 m * 500 m in a city or 1000 m * 1000 m on a highway are about 2 m. Assumes the RV downloads the HD map within 1 sec. so it requires about 16 Mbps.
Service Level Latency	[ms]	100	End-to-end, 100 ms is needed for the HD map to perform in real time.
Service Level Reliability	%	99	For safety related information, timely and reliable communication is needed. The HD map data from the HV or HD map provider is not the only way for RVs to receive surrounding information.
Velocity	[m/s]	City: 19.4 Highway: 69.4	Assume the maximum speed in city is 70 km/h, and maximum speed on highways is assumed to be 250 km/h. The max speed will meet the traffic flow needs in different regions.
Vehicle Density	[vehicle/km^2]	12,000	Maximum assumed density in urban situation.
Positioning	[m]	0.1m~0.5 m (3σ)	AVs need high absolute location positioning to estimate surrounding objects' relative location to avoid collision.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Typically, those HD map-collection and -sharing solutions are proprietary. Regulatory oversight for safety related issues is needed.

5.4.7 Infrastructure Assisted Environment Perception

Use Case Name	**Infrastructure Assisted Environment Perception: Data Distribution about Objects on the Road in the Form of Object Lists or Occupancy Grids**
User Story	When an automated vehicle enters a section of the road covered by infrastructure sensors it enrols to receive information from the infrastructure containing environment data provided by dynamic and static objects on the road. This data is used to increase the trust level of the car's own sensor observations and extends its viewing range.
Category	Autonomous driving.

Road Environment	Urban, highway, intersection.
Short Description	An automated vehicle can subscribe to an infrastructure service that provides enhanced environment information regarding dynamic and static objects on the road. The vehicle is then authenticated and enabled to receive authorised information from the local road environment. The distributed data contain frequent (e.g. every 100 ms) updates of the local road segment. They also contain rolling IDs for each vehicle with information such as location, speed, direction and size. The ID allows each vehicle to identify itself quickly in the map and transform the data into a view from its ego position (own perspective). This data is then fused into the car's automated driving stack. This fulfils two purposes: 1) the trust level of the car's own sensor observations will be increased by adding an independent source; 2) the car's view of the road is enhanced at the front and back, enabling a smoother and more prepared driving experience.
Actors	Vehicle, road and roadside infrastructure.
Vehicle Roles	Host vehicle represents the vehicle consuming the environment data. Remote vehicles represents other neighbouring vehicles; mainly moving (or static) objects in the environment data.
Road/Roadside Infrastructure	• (Mandatory) different types of sensors (RADAR, LIDAR, cameras) provide a complete picture of the dynamic road conditions. • Roads are defined by their lane designations and geometry. • Traffic signs provide laws, guidelines and timely information.
Other Actors' Roles	Not applicable.
Goal	Increases trust in the HV's sensor perception data and enhances the viewing range which can sometimes be limited or obstructed by other vehicles, road bends or dips, intersections or limited sensor range.
Needs	The HV needs to receive and fuse environment data received with its own sensor data to improve situation awareness and reliability.
Constraints/ Presumptions	• The road infrastructure provides the sensor infrastructure, data and processing capabilities to perform sensor data fusion and communicates the results in real time. • The HV is authorised and can enrol in the service provided by the road infrastructure. • HV and road infrastructure can establish a secure communication link. • HV and road infrastructure are able to mutually authenticate. • HV has implemented a flexible automated driving software stack enabling the fusion of perception data from external sources with the HV's own perception data.
Geographic Scope	Locations with well-developed city, road and traffic infrastructure.

Illustrations	
Pre-Conditions	• The road infrastructure has access to means allowing it to capture sensor data, process and fuse this data, as well as store and send it to the HV and other vehicles in real time. • The HV is equipped with onboard devices that provide the means to receive and process data from the infrastructure. • The HV already has precise map data on the road layout.
Main Event Flow	• On entering the zone with infrastructure coverage, the HV and infrastructure perform an initial handshake to establish a secured communication link. • During the initial handshake the basic technical capabilities of the HV are communicated to the infrastructure to be used for different services that it provides. • As basic functionality, the infrastructure’s sensors track all moving vehicles including the HV, so its location is known. • The infrastructure and vehicle agree on a secure communication scheme; for example, encryption keys can be employed to check the integrity of the messages or to prevent hackers posing as infrastructure either by themselves or as a man-in-the-middle attack. • Infrastructure enumerates the available services to the HV. • HV picks the local dynamic map (LDM) data service. • Infrastructure and vehicle agree on an ID for the vehicle that will be used as identification inside the broadcasted environment data (for privacy reasons a rolling ID scheme is agreed). • By participating, the vehicle starts to receive the environment data from the infrastructure. • The HV merges external perception data with its own data and optimises its driving decisions.
Post-Conditions	• The HV has left the area of infrastructure support. • A sign-off is performed and the car continues using its own sensors only.
Information Requirements	• Infrastructure sensor data including video streams. • Road conditions. • RVs’ status (e.g. location, dynamics etc). • Lane designations and geometry. • HV’s status (location, speed, etc.).

User Story #1

(Data Distribution about Objects on the Road in Form of Object Lists or Occupancy Grids)

Service Level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Range	[m]	500	Typical sensor range expected for one of several roadside infrastructure nodes.
Information Requested/Generated	Quality of information/ Information needs	From RADAR to local compute unit for sensor fusion 40-160 Kbps From cameras to local compute unit 40-120 Mbps per camera (video streaming): ~8 Mbps compressed video per camera From LIDAR sensors to local compute unit: 35 Mbps per sensor From Infrastructure to HV 40-4000 Kbps From edge to edge 40-4000 Kbps	Assumes RADAR sensors already generate object lists for observed vehicles, then the required data rate depends on traffic density. The number of cameras needed depends on the complexity of the roads including the number of lanes. Each camera is separately connected to the edge computer. This assumes also H264 compression. Video pre-processing, detection and classification of objects by camera is computationally intensive, therefore connecting more than two cameras to a state-of-the-art server is currently unlikely. Assuming each LIDAR sensor creates point clouds and not object lists. The value depends on whether object lists or occupancy grid information is transmitted. Object lists can contain dynamic information about speed and direction. This also depends on how many objects are reported. Each edge node is responsible for a certain section of highway, for example 1-2 km in length. Sensors on this section of the road are connected to at least one edge node which is then generating an environmental map for this 1-2 km road section. As vehicles travel along the highway they pass through different sections consecutively. Likewise, the knowledge about these vehicles needs to travel from edge node to edge node. The first edge node transmits the information about all observed objects to the next node in line. This node then starts to observe relevant objects using its own sensors and needs to match these observations with the information it receives from the previous edge node. This is necessary in order to continuously track and guide each vehicle. Therefore, edge nodes need some form of wired or wireless connection to each other. The data rate requirement is similar to an edge-to-vehicle

			transmission, in the case of broadcasting the objects detected on the road.
Service Level Latency	[ms]	From infrastructure to HV 100	Total from sensor detection to vehicle including sensor fusion on the edge = 100 ms. Depends on the reaction time needed, which is directly related to the maximum driving speed allowed. For instance, at a speed of 50 km/h, the HV will move 0.27 m within 20 ms.
Service Level Reliability	%	From sensors to edge compute node: 99 Infrastructure to HV: 99.99 (Very high)	This is comparable to the sensor inside the car. This Use Case applies augmented sensor data that the car retrieves itself resulting in slightly relaxed requirements compared to User Story #2. This service is still regarded as safety critical. If the infrastructure fails it must 'fail silently' or provide quantitative data about the service degradation (e.g. position precision falls from 10-100 cm).
Velocity	[m/s]	69.4	~250 km/h is the maximum relative speed between infrastructure and vehicles. Common assumptions of 500 km/h are not needed here because the infrastructure cannot move away from the vehicle.
Vehicle Density	[vehicle/km^2]	1200 vehicles/km2 at 20 km/h A maximum of around 400 vehicles (200 in each direction), i.e. 2% of this density receive the service	Around 200 vehicles will fit on a 1 km highway strip with three lanes in each direction. Assumptions: • Lane width of 3 m (for the two directions around 20 m). • Inter-vehicles distance required in traffic jam (max. speed 20 km/h): 11 m. • Average vehicle length of 4.5 m. • Assumes three highway crossings (bridges).
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane, and to navigate through small gaps between two or more objects.
Interoperability/ Regulatory/	[yes/no]	Yes/Yes/Yes	The same infrastructure needs to interact with all vehicle types.

Standardisation Required			Regulation is needed because authorities may need to specify maximum speed, minimum accuracy etc.

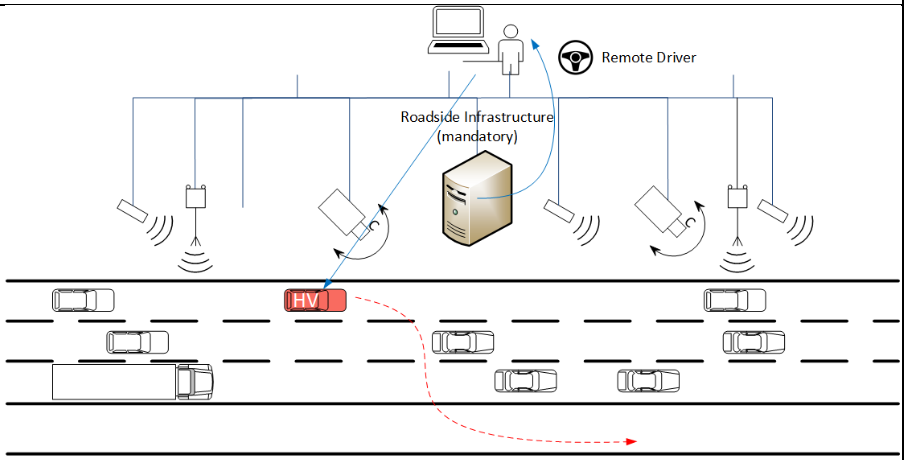
User Story #2 **(Individual Data Transmission in Form of Trajectories or Actuation Commands)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	500	Typical sensor range expected for one of several roadside infrastructure nodes.
Information Requested/Generated	Quality of information/ Information needs	From RADAR to local compute unit for sensor fusion 80-160 Kbps From cameras to local compute unit 40-120 Mbps per camera (video streaming): ~8 Mbps compressed video per camera From LIDAR sensors to local compute unit: 35 Mbps per sensor From LIDAR sensors to local compute unit: 35 Mbps per sensor	Assuming RADAR sensors already generate object lists for observed vehicles then the required bandwidth depends on traffic density. The number of cameras needed depends on complexity of road including number of lanes. Each camera is separately connected to the edge computer. This assumes also H264 compression. Video pre-processing, detection and classification of objects by camera is computationally intensive, therefore connecting more than two cameras to a state-of-the-art server is currently unlikely. Assuming each LIDAR sensor create point clouds and not object lists. When transmitting trajectories, and assuming 10 waypoints plus velocity per trajectory, one trajectory is 1664 bytes in size. For instance, when sending every 100 ms to 500 cars this results in a data rate of 64 Mbps. Each edge node is responsible for a certain section of highway, for example 1-2 km in length. Sensors on this section of the road are connected to at least one edge node which is then generating an environmental map for this 1-2 km road section. As vehicles travel along the highway they pass through different sections consecutively. Likewise, the knowledge about these vehicles needs to travel from edge node to edge node. The first edge node transmits the information about all observed objects to the next node in line. This node then starts to observe relevant objects using its

		From infrastructure to HV 64 Mbps From edge-to-edge 400-4000 Kbps	own sensors and needs to match these observations with the information it receives from the previous edge node. This is necessary in order to continuously track and guide each vehicle. Therefore, edge nodes need some form of wired or wireless connection to each other. The data rate requirement is similar to the one for the edge-to-vehicle in the case of broadcasting the detected objects on the road.
Service Level Latency	[ms]	From infrastructure to HV 100	Total from sensor detection to Vehicle including sensor fusion on edge = 100 ms. Depends on the reaction time that is needed, which is directly related to the maximum driving speed allowed. For instance in a speed of 50 km/h, the HV will move 0.27 m within 20 ms.
Service Level Reliability	%	From sensors to edge compute node: 99 Infrastructure to HV: 99.999 (Very high)	This is comparable to the sensor inside the car. The requirement here is very high since the HV is following the trajectory blindly.
Velocity	[m/s]	35	~120 km/h is an average convenient speed for longer distance on the highway. Assuming dedicated lanes for this Use Case, the infrastructure is basically coordinating all vehicles, with all vehicles in those lanes being HV. Therefore, it is comparable to platooning and the danger of collision between HVs is reduced.
Vehicle Density	[vehicle/km^2]	1200 vehicles/km2at 20 km/h A maximum of around 400 vehicles (200 in each direction), i.e. 2% of this density have the service	Around 200 vehicles will fit in 1 km highway strip with three lanes in each direction. Assumptions: • Lane width of 3 m (for the two directions around 20 m). • Inter-vehicle distance required in traffic jam (maximum speed 20 km/h): 11 m. • Average vehicle length of 4.5 m. • Three highway crossings (bridges).

		provided to them	
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	The same infrastructure needs to interact with all vehicle types. Regulation is needed because authorities may need to specify maximum speed, minimum accuracy, data formats, etc. may need to specify maximum speed, minimum accuracy etc.

5.4.8 Infrastructure-Based Tele-Operated Driving

Use Case Name	**Infrastructure-Based Tele-Operated Driving**
User Story	When the automated vehicle detects a failure in a critical subsystem it prepares a status report and using its geo-position performs the necessary safety function (e.g. slow down or stop) and transmits all information to the tele-operator. Assuming the incident location is covered by infrastructure sensors the tele-operator retrieves a real-time picture of the road environment centred around the HV. Based on the perceived situation and the capabilities of the car, the remote driver can provide the appropriate trajectory and manoeuvre instructions to help the autonomous vehicle move to a safer location.
Category	Autonomous driving.
Road Environment	Urban, highway, intersection.
Short Description	An automated vehicle (e.g. passenger cars, shuttles or buses) may detect a failure in either computing or sensor components that are critical for the automated driving functionality. Without external support this may lead to a safety function (a full stop) being performed/implemented. Depending on where this happens (e.g. highway or in front of traffic lights) this can be a safety hazard or a mere inconvenience for the host vehicle's occupants or other vehicle's drivers. A human driver could be overwhelmed by this situation (e.g. if the HV stops at the left-most lane on a highway and asks for help from a tele-operator). A tele-operator supported by infrastructure sensors will be able to assess both the position of the HV and that of other vehicles and pedestrians in the vicinity. The tele-operator will then guide the HV either by remote-steering or remote-driving support to the nearest safe location (e.g. safety lane on the highway or parking spot in the city). This Use Case can be potentially extended by accessing other parts of the traffic infrastructure, such as traffic lights or warning and speed limit signs, in order to further support the safe driving of the HV.
Actors	Vehicle, remote driver, road and roadside infrastructure.

Vehicle roles	Host vehicle represents the remotely driven vehicle. Remote vehicles represents other neighbouring vehicles.
Road & Roadside Infrastructure	• (Mandatory) different types of sensors (RADAR, LIDAR, cameras) provide a complete picture of the dynamic road conditions. • Roads are defined by their lane designations and geometry. • Traffic signs provide laws, guidelines and timely information.
Other Actors' roles	Remote driver (human or machine) takes over the HV for a short period of time to overcome a dangerous or complex situation en route.
Goal	Enables the remote driver to support the HV remotely in the absence of sensor data from the HV itself.
Needs	The HV needs to receive and apply the driving instructions sent by the remote driver.
Constraints/ Presumptions	The road infrastructure provides the sensor infrastructure, data and processing capabilities to enable remote driving functionality: • The HV is authorised and can enrol in the service provided by the road infrastructure. • HV and road infrastructure can establish a secure communication link. • HV and road infrastructure are able to mutually authenticate.
Geographic Scope	Locations with well-developed city, road and traffic infrastructure.
Illustrations	
Pre-Conditions	• The road infrastructure has the means allowing it to capture sensor data, store, process and fuse this data, perform remote driving functions and send remote driving commands to the HV in real time. • The HV is equipped with onboard devices that provide the means to receive and process data from the infrastructure. • The HV has detected a situation that leads to the reduced functionality of sensors needed for automated driving. • The HV has asked and established an authenticated and secure communication link with the remote driver/operator.
Main Event Flow	• On entering the zone with infrastructure coverage, the HV and infrastructure perform an initial handshake to establish a secured communication channel and speed up emergency communication. • During the initial handshake, basic technical capabilities of the HV are communicated to the infrastructure used for different

	• services that it provides, among others for the tele-operator or remote driving function. • As basic functionality, the infrastructure's sensors track all moving vehicles including the HV so its location in case of emergency is known. If the remote driver is a machine then: • The HV vehicle informs the remote driver about its emergency situation and sends an update regarding faulty subsystems. • A repair service is alerted in parallel. • Because of the pre-established relationship between the HV and infrastructure a seamless handover between HV and remote driver is possible, potentially reducing the speed of the HV. • The necessary information to build a model of the surroundings and the HV's own speed, direction and location is already available to the remote driver because it is continuously generated by infrastructure sensors. • If the automated HV is capable of following complete trajectories the infrastructure provides one or several safe emergency trajectories to the HV. • The HV selects the trajectory based on distance and comfort, and executes it. • New trajectories are generated repeatedly until the HV is safely at its destination. • If the HV cannot process trajectories then the remote driver takes over control of the car's actions. • If available, secondary information from other vehicles is accessed to obtain a more holistic view of the situation. • Feedback is provided to the remote driver in parallel with the execution of the manoeuvre.
Alternative Event Flow	If the remote driver is a human then: • The HV needs to stop before a human driver can take over. • Based on infrastructure sensors including cameras, a virtual view of the environment is provided to the remote driver (similar to a video game), which can be augmented with raw video streams (real camera data from the infrastructure is added). • The infrastructure sensor data can be augmented by sensor data from other vehicles. • The remote driver analyses the situation and selects the appropriate trajectory and/or the manoeuvre instructions that will help the HV to resolve the corresponding situation where uncertainty is high. • The remote driver sends to the HV trajectory and/or manoeuvre instructions and executes them, according to HV's onboard security checks. • Simulated feedback and video data from an appropriate infrastructure camera is provided to the remote driver in parallel with the execution of the manoeuvre.
Post-Conditions	The HV has left from the point where support was needed. The remote driving support session is de-activated and the HV can wait for the repair service at a safe location.

Information Requirements	• Infrastructure sensor data including video streams. • Road conditions. • RVs' status (e.g. location, dynamics, etc.). • Traffic signs. • Traffic information. • Lane designations and geometry. • HV's status (location, speed, etc.). • HV's trajectory. • HV's manoeuvre instructions (steering wheel, acceleration and brake pedal inputs).

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	1000	Maximum driving distance from the start of an emergency until safe stop.
Information Requested/Generated	Quality of information/ Information needs	From RADAR to local compute unit for sensor fusion 80-160 Kbps From cameras to local compute unit 5-8 Mbps per camera (video streaming) From LIDAR sensors to local compute unit: 35 Mbps per sensor From infrastructure to remote driver: stream of environment data after	Assumes RADAR sensors already generate object lists for observed vehicles, then the required bandwidth depends on traffic density. The number of cameras needed depends on the complexity of the road including number of lanes. Each camera is separately connected to the edge computer. This assumes also H264 compression. Video pre-processing, detection and classification of objects by camera is computationally intensive, therefore connecting more than two cameras to a state-of-the-art server is currently unlikely. Assuming each LIDAR sensor create point clouds and not object lists. This could happen on the same compute node. Therefore this speed requirement will be handled by local buses like Peripheral Component Interconnect Express (PCIe). Pre-processed environment model data e.g. in form of object lists that contain among others vehicle types, sizes, speed and direction requires only limited bandwidth, depending on the number of objects in the environment model this is estimated between 50-500 Kbps. From remote driver to HV: A machine-based remote driver will most likely transmit trajectories instead of direct actuation commands. The size of command

		sensor fusion at the edge From remote driver to HV: up to 1000 bytes per message (up to 400 Kbps) (Commands from remote driver)	messages, e.g. a) turn steering wheel, direction, angle, etc., b) apply the brake, brake pressure, etc. including appropriate security headers. The command messages will be sent every 20 ms (maximum 50 messages per second).
Service Level Latency	[ms]	From infrastructure to remote driver: 50 From remote driver to HV: 50	Round trip time = 100 ms From remote driver to HV: depends on the reaction time needed, which is directly related to the maximum driving speed allowed. For instance, at a speed of 50 km/h, the HV will move 0.27 m within 20 ms.
Service Level Reliability	%	From sensors to edge compute node: 99 From remote driver to HV: 99.999 (Very high)	This is comparable to the sensor inside the car. From remote driver to HV: the transmission of commands or paths from the remote driver requires a very high level of reliability because this affects the safe and efficient operation of the AV. In addition, the video streams and/or sensor information should be sent with ‘high reliability’ to make sure that the remote driver has the correct (current) view of the surroundings.
Velocity	[m/s]	2.78	<10 km/h is considered the maximum speed for remote steering under highly uncertain conditions.
Vehicle Density	[vehicle/km^2]	1,200 vehicles/ km2 at 20km/h A maximum or around 10 vehicles, i.e. 0.05% of the total density,	Around 200 vehicles will fit on a 1 km highway strip with three lanes in each direction. Assumptions: • Lane width of 3 m (for the two directions around 20 m).

		have the service provided to them.	• Inter-vehicles distance required in traffic jam (maximum speed 20 km/h): 11 m. • Average vehicle length of 4.5 m. • Three highway crossings (bridges). Vehicle density reflects the number of HVs. Many more RVs could be present.
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability and standardisation is needed between the infrastructure (e.g. camera) and the Tele-Operated Driving server. It is possible, however, that the edge servers are set up as a multi-tenant system where each car OEM runs its own system. Regulation is needed because authorities may need to specify maximum speed, minimum accuracy, data formats, etc.

5.4.9 Remote Automated Driving Cancellation (RADC)

Use Case Name	**Remote Automated Driving Cancellation**
User Story	High automated/autonomous driving level of an AD vehicle has to be immediately cancelled for safety reasons. This can be triggered by a number of criteria, including lack of network coverage, insufficient KPIs and SLAs, unusual and/or unsafe driving conditions, etc.
Category	Autonomous driving.
Road Environment	Any type of road.
Short Description	Due to unexpected and unpredictable reasons leading to safety concerns, the high automated/autonomous level of an AD vehicle has to be cancelled. As a result, the control of the car has to be given to a remote tele-control operator or to the driver of the vehicle, if there is one. The remote control can be provided via another vehicle, a remote driver, a set of relays on roadside infrastructure, or by a remote operator in the cloud, etc.
Main Actors	AD vehicle/s.
Vehicle Roles	Host vehicle in AD mode.

Roadside Infrastructure Roles	For example, roadside units (RSU) communicating with the HV.
Other Actors' Roles	For example, other (remote) vehicles in the proximity of the HV communicating with the HV.
Goal	Dangerous traffic situations that could arise in AD mode have to be avoided immediately by cancelling the AD level remotely.
Needs	The AD HV needs to receive immediate information and sufficient instructions about the cancellation of the AD level in its vicinity (i.e. on its section of the road), and transfer the vehicle to a safe 'temporary' mode, where an alternate driving method can take over the HV.
Constraints/ Presumptions	• HV's initial network connection (e.g. AD mode started with…) is not available, or the available SLA (e.g. required QoS) is not sufficient to meet the needs of the HV's AD mode. • Autonomous driving cancellation (ADC) message is supported in the network.
Geographic Scope	Everywhere.
Pre-Conditions	• Capability of initial network (MNO) to detect that the AD HV is not reachable. • Capability of initial network to trigger other networks (provided by other MNOs) with possible network coverage in the vicinity of the AD HV (i.e. through enhanced multi-operator interworking). • Capability of initial network to trigger an ADC message for an AD HV via other network connections (e.g. RSU, RV, sidelink or Uu).
Main Event Flow	• HV is in steady state mode in autonomous mode. • HV in high (highest) AD level is approaching a road section where it is unsafe at that current level. • ADC mechanism is triggered. • ADC message is sent to the HV by a. Initial network (Uu) b. Other networks (provided by other MNOs) c. Other network connections (e.g. RSU, RV, sidelink) • HV receives an ADC notification to discontinue AD. • HV applies an ADC and in self-control mode moves the vehicle to a safe location. Note: Additional information is provided to the vehicle for the next steps, but this is a different Use Case (i.e. remote control).
Post-Conditions	• Acknowledgement of an ADC message is sent by the HV and confirmation that the AD has been exited or changed. • A subsequent action can include remote control operation of the vehicle, as well as non-AD (autonomous/automated) driving mode engaged. Implications on other Use Cases: • If HV is in platooning mode, the vehicle needs to first exit the platoon safely.

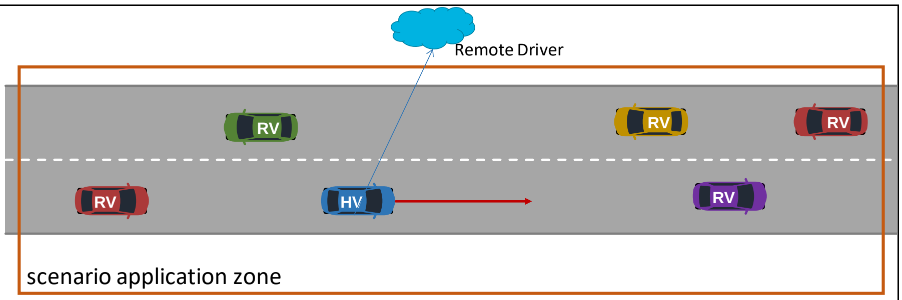
Information Requirements	• ADC command needs to be successfully received. • ADC subsequent action.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	> 1000	Notification range from communication network for the need of an AD change in order to have enough time to change AD mode to a lower mode and inform a passenger to undertake the driver’s role (this last transition time can last 20 s-30 s).
Information Requested/Generated	Quality of information/ Information needs	From network to the AD vehicle: ~ 300 bytes (DL) And Feedback from vehicle to network < 300 bytes (UL)	Network message size for notification of a basic safety message. And message from a car as feedback (a handshake) on the safety message. Note 1: the message assumes no trajectory or polygon information about the route or area with AD degradation, or multiple quality of service degradation levels on the trajectory or area involved. Note 2: the message frequency assumes: 0.02 Hz.
Service Level Latency	[ms]	100	Considering the maximum assumed speed (250 km/h) and the handover time required to switch from the automated driving mode to a human driver, 100 ms is the estimated required time for transmitting the remote automated driving cancellation.
Service Level Reliability	%	99.999	Reliability to be reached until the HV arrives at the QoS degradation area.
Velocity	[m/s]	69.4	This Use Case could be applied to all types of road environments. The maximum speed in highway areas is considered to be 250 km/h.
Vehicle Density	[vehicle/km^2]	1500	Vehicle density reflecting the number of HVs (all of them driving in the same direction) would need this QoS degradation notification message.
Positioning	[m]	10 (1σ)	The notification should be precise enough in terms of position to allow early RADC,

			and it also depends on the road environment (proportional to HD map resolution).
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	At a first implementation phase, an OEM can instruct its vehicles to deactivate the AD mode, but in the future a third party may undertake this role, hence interoperability and standardisation are required. Regulation is also required, since safety procedures are involved.

5.4.10 Tele-Operated Driving

Use Case Name	**Tele-Operated Driving (TOD)**
User Story	A temporary health issue (e.g. illness, headache) of a driver impairs his/her concentration, reactions and judgement, and consequently affects his/her ability to drive safely. The driver of the vehicle (with some autonomous capabilities) asks a remote driver to take control of the vehicle and drive the vehicle in an efficient and safe manner, from the current location to the destination.
Category	Autonomous driving.
Road Environment	Urban, rural, highway, intersection, parking area.
Short Description	Based on the perceived environment, the remote driver provides to the vehicle that is remotely driven the appropriate trajectory and manoeuvre instructions to navigate to the destination efficiently and safely.
Actors	Vehicle, remote driver, road and roadside infrastructure.
Vehicle Roles	Host vehicle represents the remotely driven vehicle, and remote vehicles.
Road/Roadside Infrastructure	• Roads are defined by their lane designations and geometry. • Traffic signs provide laws, guidelines and timely information.
Other Actors' Roles	Remote driver (human or machine) undertakes to drive the HV remotely.
Goal	Enables the remote driver to control the HV remotely.
Needs	The HV needs to receive and apply the driving instructions sent by the remote driver.
Constraints/ Presumptions	The HV provides the infrastructure and data to enable remote driving functionality.
Geographic Scope	Everywhere.

<table>
<tr><td>Illustrations</td><td></td></tr>
<tr><td>Pre-Conditions</td><td>The remote driver has established an authenticated and secure communication channel with the HV.</td></tr>
<tr><td>Main Event Flow</td><td>If the remote driver is a machine then:
• The remote driver receives road conditions (e.g. obstacles) and status information of neighbouring RVs (e.g. location, speed, dynamics, etc.) derived, for example, by the HV's sensors and status information (e.g. speed, location), and traffic conditions.
• The remote driver, based on the received information, builds the model of its surroundings (i.e. awareness of the environment of the HV) and, taking into account the destination point, selects the trajectory and manoeuvre instructions.
• The HV receives from the remote driver trajectory and/or the manoeuvre instructions and executes them, according to the HV's onboard security checks.
• Feedback is provided to the remote driver in parallel with the execution of the manoeuvre.</td></tr>
<tr><td>Alternative Event Flow</td><td>If the remote driver is a human then:
• The remote driver receives high-quality video streams (e.g. to identify road conditions, neighbouring RVs) and the HV's status information (e.g. speed, location).
• The remote driver, based on the received information, builds his/her situation awareness and, taking into account the destination point, selects the trajectory and manoeuvre instructions.
• The HV receives from the remote driver trajectory and/or manoeuvre instructions and executes them, according to HV's onboard security checks.
• Feedback is provided to the remote driver in parallel with the execution of the manoeuvre.</td></tr>
<tr><td>Alternative Event Flow</td><td>If the remote driver has to communicate with a passenger or any person outside of the vehicle (e.g. policeman) then:
• An audio stream is also established between the remote driver and the vehicle (passenger or outside person).
• The audio stream ends when the communication is no longer needed.</td></tr>
<tr><td>Post-Conditions</td><td>The HV adjusts its trajectory, speed, acceleration, etc. based on received control information. When the vehicle has reached its destination then the remote driving process ends.</td></tr>
<tr><td>Information Requirements</td><td>• Video streams.
• Audio communication.
• Car sensor data (RADAR, LIDAR, etc.).
• Road conditions.</td></tr>
</table>

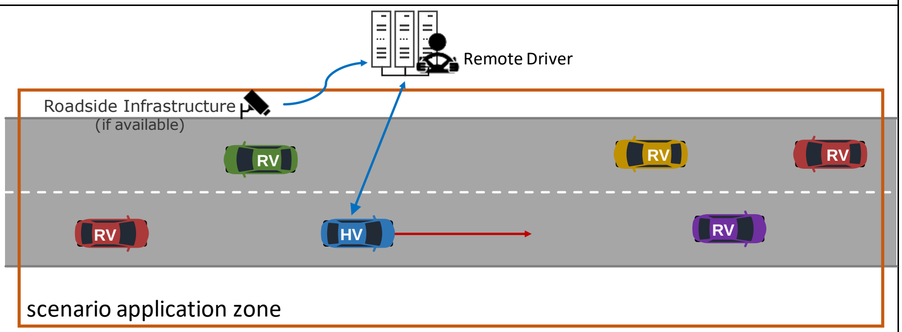
	• RVs' status (e.g. location, dynamics, etc.). • Traffic signs. • Traffic information. • Lane designations and geometry. • HV's status (location, speed, etc.). • HV's trajectory. • HV's manoeuvre instructions (steering wheel, acceleration and brake pedal inputs).

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	10,000	Assuming V2N: communication range within the coverage of a macro cell.
Information Requested/Generated	Quality of information/ Information needs	From HV to remote driver: 32 Mbps (video streaming) Or From HV to remote driver: 36 Mbps (if video streaming and object information is sent) From remote driver to HV: up to 1000 bytes per message (up to 400 Kbps) (commands from remote driver)	From HV to remote driver: ~8 Mbps are needed for a progressive high-definition video/camera (H264 compression). Four cameras are needed (one for each side): 4 * 8 = 32 Mbps. From HV to remote driver (optional): sensor data (interpreted objects) are also provided from the HV to the parking remote drive. Assuming 1 kB/object/100 ms and 50 objects, the result is 4 Mbps. From remote driver to HV: the size of command messages, e.g. a) turn steering wheel, direction, angle, etc., b) apply the brake, brake pressure, etc. including appropriate security headers. The command messages will be sent every 20 ms (maximum 50 messages per second).
Service Level Latency	[ms]	From HV to remote driver: 100 From remote driver to HV: 20	From remote driver to HV: depends on the reaction time needed, which is directly related to the maximum driving speed allowed. For instance, at a speed of 50 km/h, the HV will move 0.27 m within 20 ms.

Service Level Reliability	%	From HV to remote driver: 99 From remote driver to HV: 99.999 (Very high)	From remote driver to HV: the transmission of commands or paths from the remote driver requires a very high level of reliability because this affects the safe and efficient operation of the AV. In addition, the video streams and/or sensor information should be sent with ‘high reliability’ to make sure that the remote driver has the correct (current) view of the surroundings.
Velocity	[m/s]	13.9	50 km/h is considered the maximum speed for remote steering under highly uncertain conditions.
Vehicle Density	[vehicle/km^2]	10	Vehicle density reflects the number of HVs. Many more RVs could be present.
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Typically, these ToD solutions are proprietary implementations. Regulation is needed because authorities may need to specify maximum speed, minimum accuracy, data formats, etc.

5.4.11 Tele-Operated Driving Support

Use Case Name	**Tele-Operated Driving Support**
User Story #1	Tele-Operated Driving Support: remote steering An autonomous vehicle (e.g. passenger car or even a vehicle that performs dedicated tasks in very complex environments, e.g. snow ploughing, cleaning, loading and unloading) may detect a highly uncertain situation and cannot make the appropriate decision for a safe and efficient manoeuvre. In this case the autonomous vehicle can ask for the support of a remote driver in order to resolve the difficult situation and then switch back to the normal autonomous driving mode without the remote driving support.
Category	Autonomous driving.
Road Environment	Urban, rural, highway, intersection.
Short Description	When the autonomous vehicle detects the need for remote support, it starts sharing video and/or sensor data (e.g. from RADAR and LIDAR sensors in either raw or pre-processed form) and/or ‘situation interpretation’ data to communicate what is going on in the environment to the remote driver. Based on the perceived situation, the remote driver can provide the appropriate trajectory and manoeuvre instructions to help the autonomous vehicle resolve the highly uncertain situation.

Actors	Vehicle, remote driver, road and roadside infrastructure.
Vehicle roles	Host vehicle represents the remotely driven vehicle. Remote vehicles represents other neighbouring vehicles.
Road & Roadside Infrastructure	• Roads are defined by their lane designations and geometry. • Traffic signs provide laws, guidelines and timely information. • (Optional) video feed from traffic cameras.
Other Actors' roles	Remote driver (human or machine) undertakes to drive the HV remotely for a short period of time to overcome a dangerous or complex situation en route.
Goal	Enable the remote driver to support the HV remotely.
Needs	The HV needs to receive and apply the driving instructions sent by the remote driver.
Constraints/ Presumptions	The HV provides the infrastructure and data to enable remote driving functionality.
Geographic Scope	Everywhere.
Illustrations	
Pre-Conditions	• The HV has detected a situation which is too uncertain to select a safe and efficient manoeuvre. • The HV has asked and established an authenticated and secure communication channel with the remote driver/operator.
Main Event Flow	If the remote driver is a machine then: • The HV vehicle provides to the remote driver information about the type of the HV, its destination and also information that will enable the remote driver to build the model of surroundings. This information may include road conditions derived, for example, by the HV's sensors and cameras, status information of neighbouring RVs (e.g. location, speed, dynamics, etc.), and traffic conditions. • If available, secondary information from road infrastructure is accessed to obtain a more holistic view of the situation. • The remote driver analyses the situation and selects the appropriate trajectory and/or manoeuvre instructions that will help the HV to resolve the corresponding situation where uncertainty is high. • The remote driver sends to the HV trajectory and/or manoeuvre instructions and executes them, according to HV's onboard security checks. • Feedback is provided to the remote driver in parallel with the execution of the manoeuvre.

Alternative Event Flow	• If the remote driver is a human then: • The HV vehicle provides high-quality video streams (e.g. to identify road conditions, neighbouring RVs) and its status information (e.g. speed, location, destination). • If available, secondary information from road infrastructure is accessed to obtain a more holistic view of the situation. • The remote driver analyses the situation and selects the appropriate trajectory and/or manoeuvre instructions that will help the HV to resolve the corresponding situation where the uncertainty is high. • The remote driver sends to the HV trajectory and/or manoeuvre instructions and executes them, according to HV's onboard security checks. • Feedback (video, other sensors, HV status) is provided to the remote driver in parallel with the execution of the manoeuvre.
Post-Conditions	• The HV has left from the point where the support was needed. • The remote driving support session is de-activated and the HV switches back to its normal autonomous driving mode to continue performing its planned task or the trip to its destination.
Information Requirements	• Video streams. • Car sensor data (RADAR, LIDAR, etc.). • Road conditions. • RVs' status (e.g. location, dynamics, etc.). • Traffic signs. • Traffic information. • Lane designations and geometry. • HV's status (location, speed, etc.). • HV's trajectory. • HV's manoeuvre instructions (steering wheel, acceleration and brake pedal inputs).

User Story	**Detailed description, specifics and main differences to the user story in the main template**	
User Story #2 Tele-Operated Driving Support: Remote Driving Instructions	User Story	There are also situations where uncertainty is high due to detection problems from one of the sensors (e.g. unresolved objects). For instance, a road construction area has just been set up or changed and, with that, road direction and lane markings have changed or are confusing. Such situations might need the decision of a human (tele-operator) to be resolved. The difficult situation is resolved by a remote driver who advises the HV how to proceed with the autonomous driving task. The remote driver will provide instructions to the HV, which will then execute them in its autonomous driving mode. The remote driver does not take over control of steering and acceleration. However, it is possible for the remote driver to control the brakes.
	Other Actors' Roles	Remote driver (human or machine) undertakes to send driving commands or instructions remotely (e.g. 'ignore lane marking', 'pass car blocking the road on the right/left') to the HV for a short period of time to overcome a dangerous or complex situation en route.

User Story #1 (Remote Steering)			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	10000	Assuming V2N: communication range within the coverage of a macro cell.
Information Requested/Generated	Quality of information/ Information needs	From HV to Remote driver: 32 Mbps (video streaming) Or From HV to remote driver: optional: 36 Mbps (if video streaming and object information is sent) From remote driver to HV: Up to 1000 bytes per message (up to 400 Kbps) (Commands from remote driver)	From HV to remote driver: ~8 Mbps are needed for a progressive high-definition video/camera (H264 compression). Four cameras are needed (one for each side): 4 * 8 = 32 Mbps. From HV to remote driver (optional): sensor data (interpreted objects) are also provided from the HV to the parking remote drive. Assuming 1 kB/object/100 ms and 50 objects, the result is 4 Mbps. From remote driver to HV: the size of command messages, e.g. a) turn steering wheel, direction, angle, etc., b) apply the brake, brake pressure, etc. including appropriate security headers. The command messages will be sent every 20 ms (maximum 50 messages per second).
Service Level Latency	[ms]	From HV to remote driver: 100 From remote driver to HV: 20	From remote driver to HV: depends on the reaction time needed, which is directly related to the maximum driving speed allowed. For instance at a speed of 50 km/h, the HV will move 0.27 m within 20 ms.
Service Level Reliability	%	From HV to remote driver: 99	From remote driver to HV: the transmission of commands or paths from the remote driver requires a very high level of reliability because this affects the safe and efficient operation of the AV. In addition, the video streams and/or sensor information should be sent with 'high

		From remote driver to HV: 99.999 (Very high)	reliability' to make sure that the remote driver has the correct (current) view of the surroundings.
Velocity	[m/s]	2.78	<10 km/h is considered the maximum speed for remote steering under highly uncertain conditions.
Vehicle Density	[vehicle/km^2]	10	Vehicle density reflects the number of HVs. Many more RVs could be present.
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Typically, these ToD solutions are proprietary implementations. Regulation is needed because authorities may need to specify maximum speed, minimum accuracy, data formats, etc.

User Story	**Detailed description, specifics and main differences to the user story in the main template**	
User Story #2 Tele-Operated Driving Support: Remote Driving Instructions	User Story	There are also situations where doubts are raised due to uncertain detection from one of the sensors (e.g. unresolved objects). For instance, a segment of road construction has just been set up or changed and, with that, the road direction and lane markings have changed or are confusing. Such situations might need human intervention (tele-operator) to be resolved. The difficult situation is managed by a remote driver who advises the HV how to proceed with the autonomous driving task. The remote driver will provide instructions to the HV which will then execute them in its autonomous driving mode. The remote driver does not take over control of steering and acceleration. The remote driver retains the ability to control the braking.
	Other Actors' Roles	Remote driver (human or machine) undertakes to send driving commands or instructions remotely (e.g. 'ignore lane marking', 'pass car blocking the road on the right/left') to the HV for a short period of time in order to deal with a dangerous or complex situation.

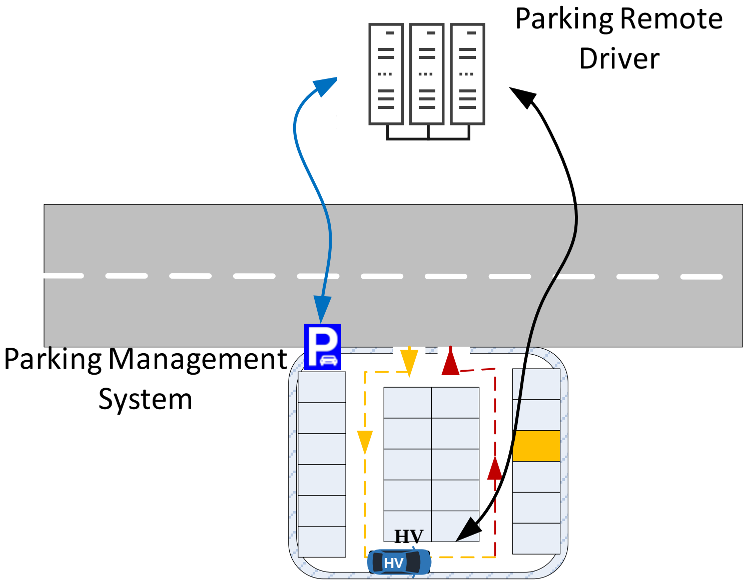
User Story #2 **(Remote Driving Instructions)**

Service Level Requirement	SLR Unit	SLR Value	Explanations/Reasoning/Background
Range	[m]	10000	Assuming V2N: communication range within the coverage of a macro cell.
Information Requested/Generated	Quality of information/ Information needs	From HV to remote driver: 32 Mbps (video streaming) Or From HV to remote driver: optional: 36 Mbps (if video streaming and object information is sent) From remote driver to HV: up to 1000 bytes per message (up to 400 Kbps) (Commands from remote driver) OR From remote driver to HV: up to 25 Kbps (Path from remote driver)	From HV to remote driver: ~8 Mbps are needed for a progressive high-definition video/camera. Four cameras are needed (one for each side): 4 * 8=32 Mbps From HV to remote driver (optional): sensor data (interpreted objects) are also provided from the HV to the parking remote driver. Assuming 1 kB/object/100 ms and 50 objects, the result is 4 Mbps. From remote driver to HV: the size of command messages, e.g. a) turn steering wheel, direction, angle, etc., b) apply the brake, brake pressure, etc. including appropriate security headers. The command messages will be sent every 20 ms (maximum 50 messages per second). From remote driver to HV: the data of provided paths are several Kbps (e.g. 100 points and 32 bytes for each point).
Service Level Latency	[ms]	From HV to remote driver: 100 From remote driver to HV: 200	From remote driver to HV: with only the instructions to be transmitted from remote driver to the HV, latency requirements are more relaxed.
Service Level Reliability	%	From HV to remote driver: 99 From remote driver to HV: 99.999	From remote driver to HV: the transmission of commands or paths from the remote driver requires a very high level of reliability because this affects the safe and efficient operation of the AV. In addition, the video streams and/or sensor information should be sent with 'high reliability' to make sure

		(Very high)	that the remote driver has the correct (current) view of the surroundings.
Velocity	[m/s]	2.78	<10 km/h is considered the maximum speed for remote steering under highly uncertain conditions.
Vehicle Density	[vehicle/km^2]	10	Vehicle density reflects the number of HVs. Many more RVs could be present.
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Typically, those ToD solutions are proprietary implementations. Regulation is needed because authorities may need to specify maximum speed, minimum accuracy, data formats, etc.

5.4.12 Tele-Operated Driving for Automated Parking

Use Case Name	**Tele-Operated Driving for Automated Parking**
User Story #1	Tele-Operated Driving for Automated Parking: Remote Driving Paths When a vehicle arrives at its destination parking area, the driver leaves the vehicle and it is parked by a remote driver located in a tele-operation centre.
Category	Autonomous driving.
Road Environment	Parking area (indoor or outdoor).
Short Description	• A vehicle arrives at its destination parking area. • The vehicle is taken over by the parking remote driver. • The vehicle is parked in the designated parking space by a remote driver.
Actors	Vehicle, parking remote driver, parking management system.
Vehicle Roles	Host vehicle represents the parking vehicle that is remotely driven.
Road/Roadside Infrastructure Roles	Not applicable.
Other Actors' Roles	• Parking remote driver constructs an accurate model of the HV's surrounding environment using information received from the parking management system and HV (e.g. vehicle sensors, video streams), and provides the driving paths and/or manoeuvre instructions for the HV.

	• The parking management system provides high-definition mapping and sensor information inside the parking area.
Goal	Enables HV parking using remote driving without the presence of passengers.
Needs	The HV receives and applies the driving path from the parking remote driver and uses this for autonomous driving in the parking lot.
Constraints/ Presumptions	• The HV provides the infrastructure and data to enable remote driving functionality. • The parking management system provides the data to identify free parking slots and their location.
Geographic Scope	Anywhere.
Illustrations	
Pre-Conditions	• The parking remote driver can construct an accurate model of the surrounding environment based on information received from the parking management system and HV. • HV has high-accuracy positioning enabled. • HV vehicle must be able to autonomously drive based on the provided path. • Authenticated and secure communication is provided between HV, parking remote driver and parking management system.
Main Event Flow	• The HV arrives in the 'pick-up/drop-off' area and requests an automated remote parking service from the parking remote driver. • The parking remote driver constructs the surrounding environment model using information provided by the HV (e.g. sensor data, type of vehicle) and parking management system (e.g. sensors and high-definition map inside the parking area), and identifies the appropriate parking spot. • The parking remoter driver estimates the driving path to the available parking slot and sends the coordinates to the HV. • The HV receives and executes the driving path instructions from the parking remote driver according to onboard security checks. • The HV provides updated information (i.e. sensor data) about its location and status to the parking remote driver. The latter

	monitors the HV's route and adapts the path if needed, according to feedback from the vehicle or parking management system.
Alternative Event Flow	Not applicable.
Post-Conditions	The HV has reached its destination and it is successfully parked in the destination parking place. The remote parking service ends.
Information Requirements	• High-definition map inside the parking area. • Positioning information. • HV information (e.g. type, size). • Video streams. • HV's path. • HV's manoeuvre instructions (steering wheel, acceleration and brake pedal inputs). • Car sensor data (RADAR, LIDAR, etc.).

User Story	**Detailed description, specifics and main differences to the user story in the main template**	
User Story Title #2 Tele-Operated Driving for Automated Parking: Remote Steering	User Story	In this user story the parking remote driver (human or machine) undertakes full control of the HV. Based on the HV's sensor information (e.g. LIDAR, RADAR), status and video streaming, the parking remote driver builds a model of the surroundings, and manoeuvre instructions (e.g. steering wheel, speed, acceleration) are sent for the route to the destination parking position.
	Main Event Flow	• The HV arrives in the 'pick-up/drop-off' area and requests an automated remote parking service by the parking remote driver. • The HV transmits to the parking remote driver the vehicles' sensor information, status and high-definition video streaming. • The parking remote driver constructs the model of surroundings, using also the parking management system information, if available, to identify the appropriate parking spot. Taking into account the destination point, it selects the manoeuvre instructions. • The parking remote drive transmits periodically to the HV the manoeuvre instructions (e.g. steering wheel, speed, acceleration). • The HV executes the driving commands received from the parking remote driver, according to the onboard security checks. • Feedback is sent from the HV to the parking remote driver as the manoeuvre is executed.

User Story #1 **(Remote Driving Paths)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**

Range	[m]	N/A	Depends on the new or alternative definition of range. In principle, the Use Case is applicable in the network service provider coverage area.
Information Requested/Generated	Quality of information/ Information needs	From HV to remote driver: 4 Mbps (Reporting from HV to parking remote driver) From remote driver to HV: Up to 25 Kbps bytes (Path sent from parking remote driver)	From HV to remote driver: sensor data (interpreted objects) provided from the HV to the parking remote driver. Assuming 1 kB/object/100 ms and 50 objects, the result is 4 Mbps. From remote driver to HV: according to the size of driving trajectory for the available parking slot sent from parking remote driver. Trajectory data comprises several Kbytes; only sent once (e.g. 100 waypoints of a route and 32 bytes for each waypoint).
Service Level Latency	[ms]	From HV to remote driver and from remote driver to HV: 100	From remote driver to HV: with only the trajectories to be transmitted from the parking remote driver to the HV, latency requirements are more relaxed. Driving at 20 km/s means 0.5 m between two commands.
Service Level Reliability	%	From HV to remote driver and from remote driver to HV: 99.999 (Very high)	From remote driver to HV: the transmission of commands or paths from the remote driver requires a very high level of reliability because this affects the safe and efficient operation of the AV. In addition, the video streams and/or sensor information should be sent with ‘high reliability’ to make sure that the remote driver has the correct (current) view of the surroundings.
Velocity	[m/s]	5.5	<20 km/h is the maximum considered speed inside the parking area.
Vehicle Density	[vehicle/km^2]	100	The number of vehicles that need to be remotely driven in the same area. Assumes 5%-10% of the parking spaces for the number of remote driving vehicles in large parking area (1000 vehicles) resulting in about 50-100 places.
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.

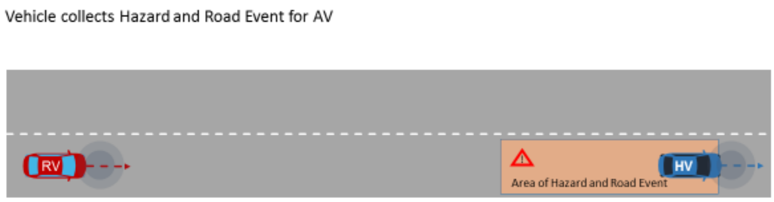
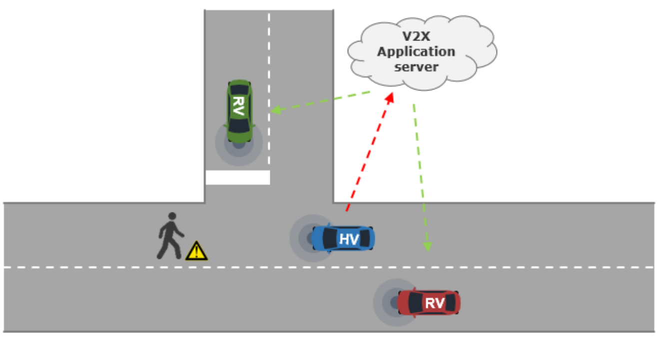
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Regulation is needed because authorities may need to specify maximum speeds, minimum accuracy, data formats, etc. Inter-operability and standardisation are also preferred since vehicles from different OEMs will be supported by the remote parking service.

User Story #2 **(Remote Steering)**			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Depends on the new or alternative definition of range. In principle, the Use Case is applicable in the network service provider coverage area.
Information Requested/Generated	Quality of information/ Information needs	From HV to remote driver: 32 Mbps (video streaming) OR From HV to remote driver (optional): 36 Mbps (if video streaming and object information is sent) From remote driver to HV: up to 1000 bytes per message (up to 400 Kbps) (Commands from remote driver)	From HV to remote driver: 15-29 Mbps are needed for a progressive high-definition video/camera. Four cameras are needed (one for each side): 4 * 8 = 32 Mbps From HV to remote driver (optional): sensor data (interpreted objects) are also provided from the HV to the parking remote driver. Assuming 1 kB/object/100 ms and 50 objects, the result is 4 Mbps. From remote driver to HV: for the steering commands, assume torque values for brake/acceleration and steering. The command messages will be sent every 20 ms (maximum 50 messages per second).
Service Level Latency	[ms]	From HV to remote driver: 100	From remote driver to HV: depends on the reaction time needed, which is directly related to the maximum driving speed allowed. For a speed of 20 km/h, the HV will move 0.14 m within 20 ms.

		From remote driver to HV: 20	Higher latency is not recommended for a parking area, where the distance between the vehicles and/or objects is short.
Service Level Reliability	%	From HV to remote driver: 99 From remote driver to HV: 99.999 (Very high)	From remote driver to HV: the transmission of commands or paths from the remote driver requires a very high level of reliability because this affects the safe and efficient operation of the AV. In addition, the video streams and/or sensor information should be sent with 'high reliability' to make sure that the remote driver has the correct (current) view of the surroundings.
Velocity	[m/s]	5.5	<20 km/h is considered the maximum speed in a parking area.
Vehicle Density	[vehicle/km^2]	100	The number of vehicles that need to be remotely driven in the same area. Assumes 5%-10% of the parking spaces for the number of remote driving vehicles in large parking area (1000 vehicles) resulting in about 50-100 places.
Positioning	[m]	0.1 (3σ)	Positioning accuracy is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/No	Regulation is needed because authorities may need to specify maximum speeds, minimum accuracy, data formats, etc. Inter-operability and standardisation are also preferred since vehicles from different OEMs will be supported by the remote parking service.

5.4.13 Vehicles Collects Hazard and Road Event for AV

Use Case Name	**Vehicle Collects Hazard and Road Event for AV**
User Story	Vehicles collect hazard and road event information based on vehicle sensor data for further use by autonomous vehicles and V2X application server.
Category	Safety.
Road Environment	Intersection, urban, rural, highway.
Short Description	Whenever a vehicle detects a hazard or road event based on its own sensor data, the corresponding information will be collected together

	with the geographic location of the vehicle for the purpose of sharing with other vehicles, especially AVs and V2X AS.
Actors	Host vehicle, remote vehicle.
Vehicle roles	HV represents the vehicle that detects events based on its own sensor data during the driving; the RV, which is typically an AV, receives information collected by the HV.
Road/Roadside Infrastructure Roles	Optionally, a roadside infrastructure role may be involved in the Use Case for receiving information from the HV and broadcasting it to the RV.
Other Actors' Roles	Optionally, a V2X application server role may be involved in the Use Case for receiving information from the HV and forwarding it to the RV.
Goal	Share road, traffic and weather event information detected by vehicles to AVs, so that the information horizon of the AVs is extended.
Needs	The AVs need prior information about the road, traffic and weather to improve their trajectory planning and motion control.
Constraints/ Presumptions	Assumptions will be required for the following information: • The HV is able to detect road, traffic and weather events based on its sensor data. • The HV is able to communicate the detected events.
Geographic Scope	Global.
Illustrations	Scenario 1  Scenario 2 Vehicle collects hazard event and sends it to the V2X AS. 
Pre-Conditions	• HV is driving through the scenario application zone ○ Defined as the area in which a road, traffic or weather event occurred

	• The scenario application zone may be a point/location, e.g. stationary car, or a trace of multiple points on the road (e.g. a slippery road segment),
Main Event Flow	• The HV detects a hazardous event (road, traffic, weather, etc.). • The HV sends out information of the detected event. • The RV is approaching the scenario application zone and receives the information directly from the HV.
Alternate Event Flow	• The HV detects a hazardous event (road, traffic, weather, etc.). • The HV sends out information of the detected event to the V2X application server. • The application server gathers and analyses the hazard information to assess potential dangers involving RVs. • The RV is approaching the scenario application zone and receives the warning information from the V2X application server.
Post-Conditions	Information about the detected hazard and road events is available and used by the RV.
Information Requirements	• HV's sensor data. • Road conditions. • Car status (e.g. location, dynamics, etc.). • Events detected by vehicles.

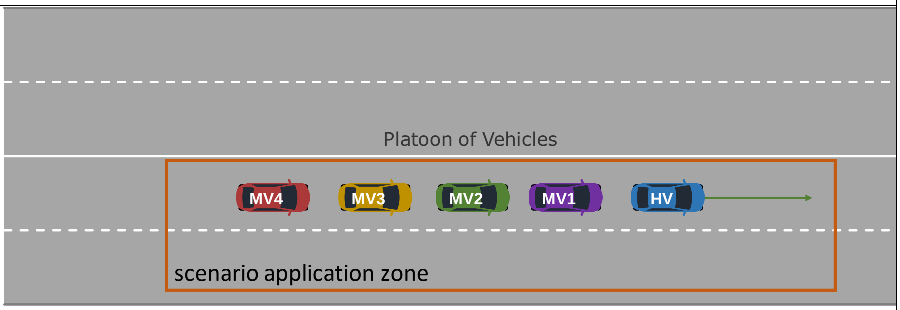
User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	Scenario 1:300 m Scenario 2: N/A	Minimum range assuming the maximum speed on a highway and 4 s response time for AVs. Needs to reach an application server.
Information Requested/Generated	Quality of information/ Information needs	300 bytes/per message	The message sent from HVs to RVs or AS contains detected event types (barriers, road work, bad weather, etc.), location, priority, etc. And the message is sent by an event trigger. The maximum size of the message is assumed to be 300 bytes.
Service Level Latency	[ms]	20	Low end-to-end latency is needed for AVs to get hazard information in time to maintain safety levels.
Service Level Reliability	%	99.9	High reliability is needed for AVs to take action based on the hazard and road event message for other vehicles.
Velocity	[m/s]	City: 19.4 Highway: 69.4	The maximum speed in a city is assumed to be 70 km/h, and the maximum speed on highways is assumed to be 250 km/h.

			The maximum speed will match the traffic levels in different regions.
Vehicle Density	[vehicle/km^2]	12,000	The maximum assumed density in urban situations.
Positioning	[m]	1.5 (3σ)	AVs need pinpoint accuracy to estimate event locations and avoid collisions. Typical positioning accuracy is needed to confirm the traffic lane.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Scenario 1: Yes/Yes/Yes Scenario 2: Yes/Yes/Yes	Interoperability between different OEMs' vehicles is needed (Scenario 1), as well as between the HD map provider and different vehicles (Scenario 2). Regulatory oversight for safety related issues is needed. Standardisation is required in the sense that the format for sensor data exchange should be commonly understood by all involved vehicles.

5.5 Platooning

5.5.1 Vehicles Platooning in Steady State

Use Case Name	**Vehicles Platoon in Steady State**
User Story	A group of vehicles (e.g. trucks travelling from warehouse facilities to a transportation area e.g. rail, ship) drive closer, in a coordinated manner, to decrease fuel consumption, increase efficiency and reduce traffic congestion. There are also potential driver and logistics efficiencies possible.
Category	Platooning.
Environment	Urban, rural, highway.
Short Description	Platooning enables a group of vehicles of the same vehicle class (e.g. cars, trucks, buses, etc.) to drive in close proximity in a coordinated manner (e.g. high-density platooning). The head of the platoon (host vehicle) is responsible for coordinating other vehicles in the group (member vehicles) and, potentially, for coordinating with cloud assistance and overall support of the platoon. By sharing status information (such as speed, heading and intentions such as braking, acceleration, etc.) between the members, and with the support of the platoon head, the distances between vehicles can be reduced, the overall fuel consumption and emissions are also reduced, together with the overall cost. Moreover, platooning enhances safety and efficiency by reducing the influence of unanticipated driving behaviour, small speed variations, and road capacity issues.

Actors	Vehicle.
Vehicle roles	There are two vehicle roles involved in this Use Case: • Host vehicle: head of a platoon. • Member vehicle: member of a platoon.
Road/Roadside Infrastructure	Not applicable.
Other Actors' Roles	Not applicable.
Goal	A number of vehicles travelling closely together that are 'electronically' connected, to reduce fuel consumption and cost.
Needs	The group of vehicles, which are coordinated/controlled by a HV, need to share common mobility patterns, to maintain formation (typically inter-vehicle distances and speed alignment) and exchange information about intended manoeuvres.
Constraints/ Presumptions	The HV and each MV are equipped to share messages conveying precise location, speed, acceleration, direction and sensor data.
Geographic Scope	Everywhere.
Illustrations	
Pre-Conditions	• A group of MVs and the HV have formed a platoon and they have authenticated each other. • The destination and the goal of the platoon are known and agreed (HV and MVs).
Main Event Flow	• The HV receives information about the road and weather conditions, if available, as well as traffic conditions according to the route that the platoon follows. • The HV also receives information about the status of the MVs (e.g. speed, location). • Based on the information collected, the HV decides the behaviour and configuration of the platoon (e.g. inter-vehicle distance guidance, speed, location and direction and intentions such as acceleration, etc.). • The MVs receive configuration information about the platoon from the HV (e.g. trajectory, speed and acceleration intention of the HV). • The MVs (e.g. MV2) receives speed, position and the intentions such as braking and acceleration of the respective front MV (e.g. MV1). • Each MV (e.g. MV2) based on the collected information, and considering its own dynamics and important parameters (e.g. tyre

	pressure), determines its driving behaviour (e.g. accelerate, brake or even to keep a stable distance with the front vehicle, i.e. MV1).
Alternative Event Flow	Not applicable.
Post-Conditions	Vehicles within the platoon maintain appropriate inter-vehicle distances, aligning their speed and driving towards the defined destination, the goal of the platoon.
Information Requirements	• Vehicles location, speed information. • Platoon trajectory. • Driving intention (brake, accelerate). • Traffic conditions. • Road conditions. • Weather conditions.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	MV-MV: 5-15 HV-MV: >175 HV-CA: Long	There are different range values considering the different interactions among involved entities in this Use Case: -Member of a platoon (MV) to member of a platoon (MV): 5-15 m is the inter-vehicle gap. Note 1: depending on antenna(s) position(s), the maximum vehicle length of 20 m has to be added to this range. Note 2: in accordance with the main event flow, MV-MV is only expected between adjacent MVs. -Head of a platoon (HV) to member of a platoon (MV): equal to the maximum length (in metres) of a platoon, which depends on the maximum length of a long vehicle (e.g. truck) and maximum inter-vehicle gap. Assuming that the maximum inter-vehicle gap is 15 m and the maximum vehicle length is 20 m, for a platoon that consists of 6 trucks (5 members and the head of the platoon) the range is: (5 * 15 m + 5 * 20) 175 m. -Head of a platoon (HV) to coordination with cloud (CA) (optional): a cloud server that assists/supports a platoon could be placed anywhere that a cloud facility is located.

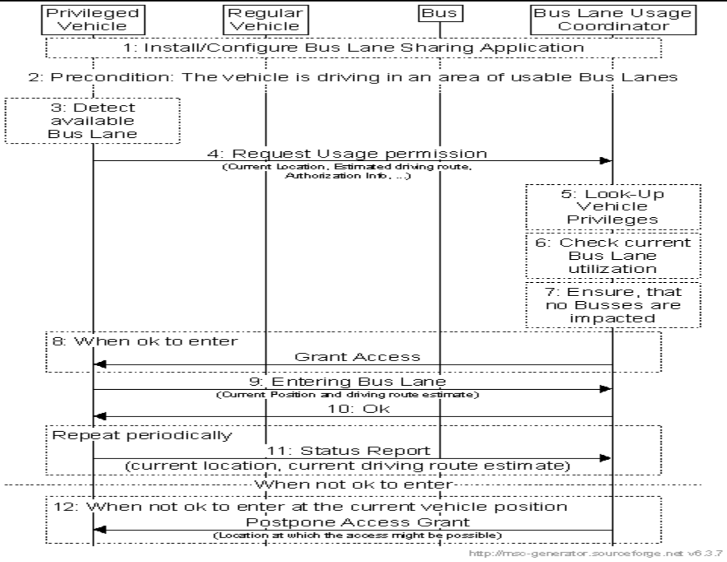
Information Requested/Generated	Quality of information/ Information needs	MV-MV: 100 bytes HV-MV: 300 bytes (20 Hz) HV-CA: 1000 bytes (event based)	Different messages are sent in line with the different interactions among entities involved in this Use Case: -Member of a platoon (MV) to member of a platoon (MV): maximum 100 bytes, since the MVs exchange speed, position and intentions such as braking, acceleration etc. The message periodicity depends on the inter-vehicle gap. Taking into account that the MVs have similar relevant speeds 10 Hz, periodicity is considered as adequate. -Head of a platoon (HV) to member of a platoon (MV): reports are provided from the MV to the HV (e.g. speed, location information), while the HV provides configuration information (e.g. trajectory, speed and the intended acceleration of the HV). The maximum length of a HV-MV message that includes path/trajectory information is 300 bytes. The messages from HV-MV are not periodic, but event-based. -Head of a platoon (HV) to coordination with cloud assistance (CA) (optional): 1000 bytes of information about the road and weather conditions, if available, as well as traffic conditions according to the route that the platoon follows. This message is not periodic. It is sent during the initial establishment and when there is an update on any of the above parameters.
Service Level Latency	[ms]	MV-MV: 50 HV-MV: 100 HV-CA: >1000	-Member of a platoon (MV) to member of a platoon (MV): for short inter-vehicle gaps, a latency of 100 ms or less is needed. -Head of a platoon (HV) to member of a platoon (MV): 100 ms may be needed for notification of important/critical changes of the status of MVs or the configuration of the platoon by the HV (e.g. trajectory change). Other messages are not that critical.- -Head of a platoon (HV) to coordination with cloud assistance (CA) (optional): this is not a time-critical interaction.

Service Level Reliability	%	MV-MV: 99.9 HV-MV: 99.9 HV-CA: 99	-Member of a platoon (MV) to member of a platoon (MV): reliability of 99.9% should be enough to allow a MV to keep a low inter-vehicle distance in a safe and efficient manner, and thus allow the maintenance of a high-density platoon. -Head of a platoon (HV) to member of a platoon (MV): reliability of 99.9% will be needed for important/critical changes of the status of MVs or the configuration of the platoon by the HV that should be notified. -Head of a platoon (HV) to coordination with cloud assistance (CA) (optional): this is not a time-critical interaction.
Velocity	[m/s]	227.8	The maximum speed of a platoon of trucks or other long vehicles is lower than 100 km/h for most countries.
Vehicle Density	[vehicle/km^2]	4500 (Highway) 9000 (Rural) 12000 (Urban)	The maximum vehicle density of the road that the platoon travels depends on the actual road environment. This parameter is useful, for example, to assess the performance of V2X communication when the load increases with traffic density. The maximum length of the platoon (in terms of involved vehicles) also depends on the type of vehicles participating in the platoon. For heavy vehicles, there are trials with six trucks involved. For other types of vehicle, the platoon could be larger.
Positioning	[m]	0.5 (3σ)	Higher than 'typical positioning accuracy to confirm traffic lane' is needed because control systems demand accuracy for lateral alignment of vehicles in platoon.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Vehicles of different OEMs need to be able to cooperate in a platoon. Regulation is needed because authorities may need to specify maximum speeds, minimum accuracy, data formats, etc.

5.6 Traffic Efficiency and Environmental Friendliness

5.6.1 Bus Lane Sharing Request

Use Case Name	**Bus Lane Sharing Request**
User Story #1	In order to improve road usage and traffic efficiency (temporary) access to bus lanes can be granted by the road authority/city. This access could be granted to certain vehicles, e.g. to create an incentive for electric and/or autonomous vehicles.
Category	Traffic efficiency and environmental friendliness, convenience, autonomous driving.
Road Environment	Urban.
Short Description	A vehicle which supports bus lane sharing features and is authorised to participate in this 'community', requests permission to use the bus lane. The vehicle sends a bus lane sharing request to the relevant application, providing the vehicle identity, its current position (e.g. where it desires to enter the bus lane) and an approximate route/trajectory (i.e. which track to follow and where the intention is to exit the bus lane). The bus lane usage application accepts the request, depending on whether the vehicle is authorised to use bus lanes and on the current traffic volume (i.e. other vehicles already granted permission to use them), as well as the position and arrival of the next bus and potentially other policies.
Actors	Vehicle, bus lane usage application.
Vehicle Roles	Vehicle applying the bus lane usage application.
Road/Roadside Infrastructure Roles	Yes.
Other Actors' Roles	Not applicable.
Goal	Increase usage in particular of urban bus lanes without impacting public transport. Promoting environmentally friendly vehicles/transport.
Needs	The vehicle needs to support interaction with the bus lane usage application.
Constraints/ Presumptions	The city may need to have the means to monitor the bus lanes strictly to prevent misuse. This could, for example, be handled by cameras on buses taking photos of licence plates and checking them against the bus lane usage application (i.e. if vehicles in bus lanes are authorised to use them).
Geographic Scope	Anywhere.

Illustrations	

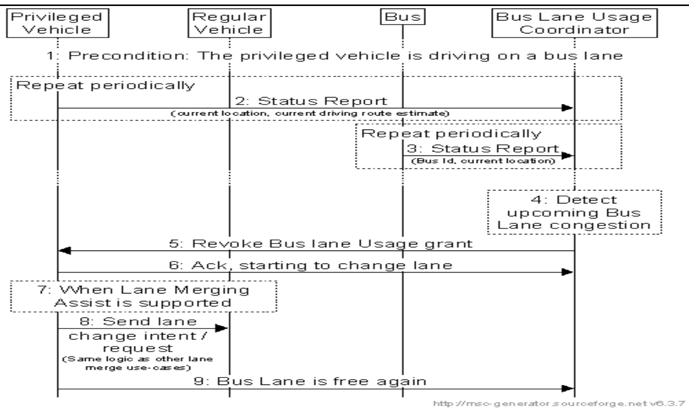
Pre-Conditions	• A vehicle is enrolled in the bus lane sharing community.
	• Law enforcement is aware that the vehicle is allowed to use bus lanes.
	• This can be done in several ways, for example:
	  o Statically: information known by law enforcement confirming the vehicle can use the bus lanes
	  o Dynamically: by informing law enforcement at the bus lane entry point
	  o Law enforcement query: direct from law enforcement vehicle, or via law enforcement back-end system, to the bus lane usage application
	  o Vehicle information: sent out from the vehicle actually in the bus lane (e.g. a valid token)

Main Event Flow	• Vehicle approaching an area with bus lanes. • Vehicle connects to bus lane usage application. • Vehicle requests access to the bus lane and provides the required information (vehicle identity, its current position or where it desires to enter the bus lane, an estimated route). • Bus lane usage application checks the request. • If accepted, the bus lane usage application sends an ‘accept’ message with instructions when and where to access the bus lane. • Vehicle informs when it is entering the bus lane. • Vehicle periodically reports its position to the bus lane usage application to control how the bus lane is used.
Alternative Event Flow	• A vehicle is enrolled in the bus lane sharing community • Vehicle approaches an area with bus lanes • Vehicle connects to bus-lane-usage application • Vehicle requests access to the bus lane and provides the required information, • Bus lane usage application checks the request, • If not accepted, the bus lane usage application sends a ‘reject’ message.
Post-Conditions	Vehicle enters/uses the bus lane.

Information Requirements	• Vehicle identifier. • Authentication information. • Positioning information.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Applicable where bus lanes exist.
Information Requested/Generated	Quality of information/ Information needs	500-1000 bytes UL and 500-1000 bytes DL	Depends on the protocol and coding used. Identifiers, authentication information, positioning information. Request and acknowledge/reject messages.
Service Level Latency	[ms]	200	The speed limit in these areas is normally not more 70 km/h (most common speed limit would be 50 km/h). 200 ms in 70 km/h zone corresponds to the vehicle moving 4 m which should be sufficient for good UC execution.
Service Level Reliability	%	99	Not a critical service, just repeat procedure if failure.
Velocity	[m/s]	19.4	In urban areas, 70 km/h is considered the maximum speed.
Vehicle Density	[vehicle/km^2]	10	Vehicle density reflects the number of vehicles with a bus sharing feature.
Positioning	[m]	1.5 (3σ)	Lane level accuracy.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/Yes	Interoperability between OEMs would not be needed since the interaction is with the infrastructure. Regulation may be needed because authorities may need to specify usage, authorisation methods, logging information, etc. Standardisation would be needed since vehicles from different OEMs will potentially support the bus lane sharing feature, and to avoid different solutions emerging in different countries (or even per city).

5.6.2 Bus Lane Sharing Revocation

Use Case Name	**Bus Lane Sharing Revocation**
User Story #1	A set of vehicles is given permission for bus lane usage, but a bus is approaching faster than initially anticipated. The lane needs to be freed up so the bus can pass without delay. The bus lane sharing usage application detects that a set of vehicles are likely to interrupt the bus, so it sends a message to 'revoke' the usage granted to relevant vehicles.
Category	Traffic efficiency and environmental friendliness, convenience, autonomous driving.
Road Environment	Urban.
Short Description	• A bus lane usage application detects an upcoming interruption of public transport by vehicles currently authorised to use the bus lane. • The bus usage application revokes the permission and instructs the relevant vehicle(s) to free up the bus lane. The vehicle acknowledges the instruction (e.g. to be used for legal reasons).
Actors	Vehicle, bus lane usage application.
Vehicle Roles	Vehicle applying the bus lane usage application.
Road/Roadside Infrastructure Roles	Yes.
Other Actors' Roles	Not applicable.
Goal	Increase usage in particular of urban bus lanes without impacting public transport.
Needs	The vehicle needs to support interaction with the bus lane usage application.
Constraints/ Presumptions	The city may need to have the means to monitor the bus lanes strictly to prevent misuse.
Geographic Scope	Anywhere.
Illustrations	
Pre-Conditions	• Vehicle has been granted permission to use the bus lane usage application.

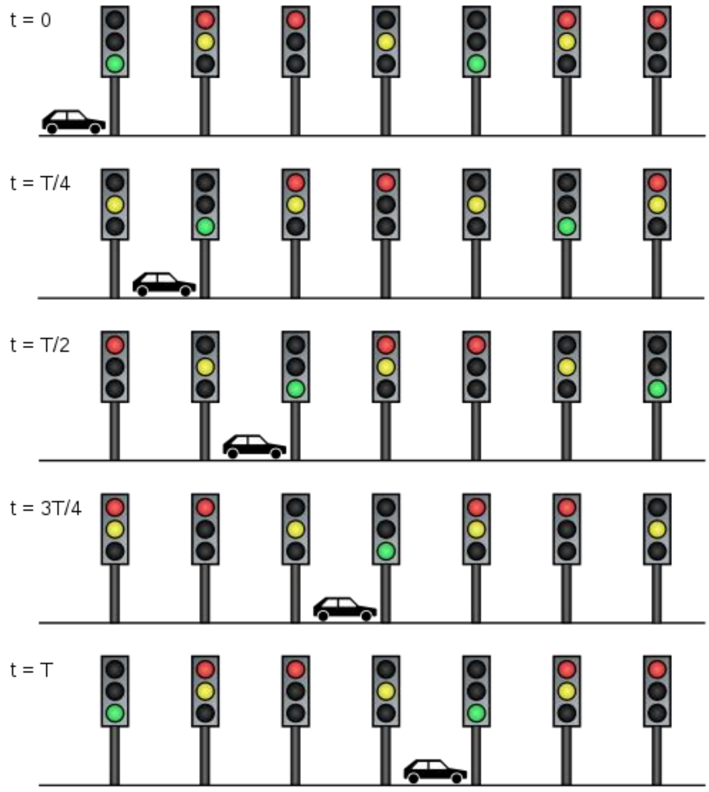
	• Vehicle is connected to the bus lane usage application. • The bus lane usage application monitors the vehicle's position.
Main Event Flow	• The bus lane usage application detects that a vehicle will interrupt the buses. • The bus lane usage application instructs the vehicle to leave the bus lane. • Vehicle confirms the instruction and leaves the bus lane (e.g. to be used for legal reasons).
Alternative Event Flow	Not applicable.
Post-Conditions	Not applicable.
Information Requirements	• Vehicle identifier. • Authentication information. • Positioning information.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Applicable where bus lanes exist.
Information Requested/Generated	Quality of information/ Information needs	500-1000 bytes UL and 500-1000 bytes DL	Depending on the protocol and coding used. Identifiers, authentication information, positioning information. Revoke and acknowledge messages.
Service Level Latency	[ms]	200	The speed limit in these areas is normally not more 70 Km/h (most common speed limit would be 50 Km/h). 200 ms in 70 Km/h zone corresponds to the vehicle moving 4 m which should be sufficient for good UC execution.
Service Level Reliability	%	99	Not critical service, just repeat procedure if failure.
Velocity	[m/s]	19.4	In urban areas, 70 km/h is considered the maximum speed.
Vehicle Density	[vehicle/km^2]	10	Vehicle density reflects the number of vehicles with a bus sharing feature.
Positioning	[m]	1.5 (3σ)	Lane level accuracy.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	No/Yes/Yes	Interoperability between OEMs would not be needed since the interaction is with the infrastructure.

			Regulation may be needed, since authorities may need to specify e.g. usage, authorisation methods, logging information etc. Standardisation would be needed since vehicles from different OEMs will potentially support the bus lane sharing feature, and to avoid different solutions emerging in different countries (or even per city).

5.6.3 Continuous Traffic Flow via Green Lights Coordination

Use Case Name	**Continuous Traffic Flow via Green Lights Coordination**
User Story	Any vehicle travelling along with the ‘green wave’ will see a progressive cascade of green lights, and will not have to stop at the intersections.
Category	Traffic efficiency and environmental friendliness.
Road Environment	Intersection.
Short Description	A series of traffic lights (usually three or more) are dynamically coordinated to allow continuous traffic flow over several intersections in one main direction. The benefits of traffic flow optimisation via dynamic traffic signal and phase changes are: reduction of CO_2 emissions, reduction of fuel consumption, reduction of cars’ waiting time at side roads, pedestrians receive more time to cross (and help to cross streets with vehicles travelling in platoons), and increased traffic efficiency in urban areas.
Actors	Vehicle, road and roadside infrastructure.
Vehicle Roles	Host vehicle represents the vehicle that approaches intersections.
Road/Roadside Infrastructure	• Roads are defined by their lane designations and geometry. • Intersections are defined by their crossing designations and geometry. • Traffic lights control right of way traffic flow through an intersection. • Local traffic laws and rules control right of way through three-way stops, four-way stops and unsigned intersections.
Goal	Helps drivers/autonomous vehicles to select the right speed setting to avoid having to stop at a series of intersections.
Needs	HV needs to know the timing of traffic lights for a progressive cascade of green lights (i.e. green wave), when approaching a series of intersections and where the HV can adapt its speed according to the timing parameter.
Constraints/ Presumptions	• HV’s intended direction through the intersection is known. • HV’s intended trajectory could be provided if available or assumed.

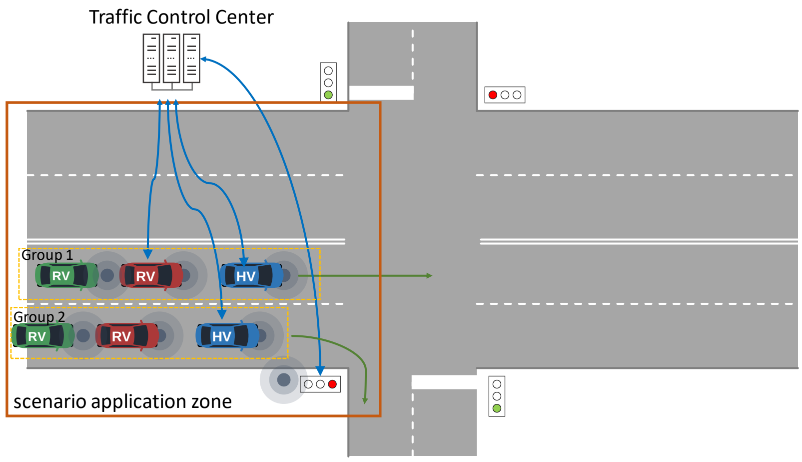
Geographic Scope	Global.
Illustrations	
Pre-Conditions	Traffic lights are dynamically coordinated to turn green in sequence, taking into account the traffic conditions and/or information from different sources if available e.g. cameras, sensors on the roads.
Main Event Flow	• The HV reports location, direction and/or intended trajectory to a traffic management server or to roadside infrastructure (this information is periodically updated). • HV is approaching a series of intersections. • HV receives timing and/or speed recommendations either by a traffic management server or by roadside infrastructure in order to follow the cascade of green lights (the timing and/or speed recommendations could be updated, while the HV passes through intersections e.g. due to change of traffic conditions). • HV displays the recommended timing and/or speed or automatically adjusts its speed.
Alternative Event Flow	Not applicable.
Post-Conditions	HV passes a series of intersections without a stop.
Information Requirements	• HV's location (including direction). • HV's intended trajectory (if available). • Lane designations and geometry. • Intersection geometry. • Traffic light signal phase and timing. • Traffic rules and laws for three-way stops, four-way stops and unsigned intersections.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	10,000	Assuming V2N: Communication range within the coverage of a macro cell.
Information Requested/Generated	Quality of information/ Information needs	From HV to traffic management server or a roadside infrastructure: 300 bytes (every 50 ms/20 Hz per participating vehicle) From traffic management server or a roadside infrastructure to HV: 300 bytes	From HV to a traffic management server or roadside infrastructure, information such as HV location (including direction) and intended trajectory are included. Assumes the size of this message is similar to a basic safety message (300 bytes). Timing and/or speed recommendations are sent from a traffic management server or by roadside infrastructure to the HV. Hence, considering that speed or timing information can be provided for a set of waypoints, then the maximum size of this message is 300 bytes. This is not a periodic message, but sent at the beginning of the service and if there is any update on the speed and/or timing recommendations. A maximum frequency of 1 Hz can be assumed for calculations.
Service Level Latency	[ms]	100	Depends on the reaction time needed to adjust the speed of the car at the current intersection. This is directly related to the maximum allowed driving speed. For instance, at a speed of 50 km/h, the car will move 1.38 m within 100 ms. 100 ms of latency for communication between the traffic management server or roadside infrastructure and the HV is assumed.
Service Level Reliability	%	95	The transmission of timing and/or speed recommendations from the traffic management server or roadside infrastructure to the HV requires a medium level of reliability, since this may affect the safe and efficient operation of the HV (especially if the speed setting needs to be modified due to an unexpected change in the sequence of traffics lights that should normally turn green). 95% reliability is assumed for the communication between the traffic

			management server or a roadside infrastructure and the HV.
Velocity	[m/s]	19.4	Maximum speed in urban areas is considered to be 70 km/h.
Vehicle Density	[vehicle/km^2]	3200 vehicle/km^2	Assumes at one intersection that there are 80 vehicles (e.g. 8 lanes considering different directions and 10 vehicles in each lane). Further assuming that there are up to 40 intersections per km^2 (e.g. in Manhattan), it results in 3200 vehicles/km^2 as an upper bound.
Positioning	[m]	1.5 (3σ)	Positioning accuracy needed by the traffic management server or roadside infrastructure in order to know the HV's location (including direction) and lane.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability is needed between vehicles of different OEMs and the traffic management server or roadside infrastructure. Regulatory oversight for safety related issues is needed. Standardisation on the application layer (message set and flow control) is desirable.

5.6.4 Group Start

Use Case Name	**Group Start**
User Story	Self-driving or semi-automated vehicles form a group to start jointly at traffic lights. In a centralised implementation of this Use Case, a traffic control centre provides tactical and strategic information to coordinate the activity.
Category	Traffic efficiency and environmental friendliness.
Road Environment	Intersection, urban.
Short Description	A traffic control centre or HV identifies several vehicles which intend to cross an intersection on a similar path at a similar time. The candidate vehicles are placed into groups following the same paths, guided through the intersection by their corresponding 'group lead' vehicle. After the manoeuvre is executed the groups are dissolved. The lead vehicle reports the manoeuvre to the traffic control centre.
Actors	• Host vehicle. • One or more remote vehicles. • Traffic control centre. • Traffic lights.
Vehicle Roles	• HV represents the lead vehicle for a given group.

	• RV represents the other group members.
Roadside Infrastructure Roles	Traffic light sends signal phase and timing information to the traffic control centre and/or to all vehicles in the vicinity
Other Actors' Roles	The traffic control centre provides tactical and strategic information to facilitate the group start activity. This happens while the vehicles are approaching the intersection and while vehicles are waiting at the red light.
Goal	Allows more efficient use of a green phase at an intersection. Reduces noise and pollution in cities. Increases convenience for drivers thanks to shorter waiting times.
Needs	• A HV detects the benefit of the Use Case and its potential implementation at an intersection, and initiates the Use Case. • The traffic control centre identifies that multiple vehicles are approaching an intersection and intend to cross it on the same path and at a similar predicted time.
Constraints/ Presumptions	• There is a mixture of vehicles which are capable and vehicles which are not capable of participating in the group start Use Case waiting at or approaching the traffic light. Vehicles without such capabilities are regarded as the group 'delimiter'. The next group, which is independent of the 'non-capable' one, is expected to start independently of the first group. • The vehicles waiting at or approaching the traffic light have different capabilities (e.g. in terms of achievable acceleration, sensor equipment). • There are more vehicles at the light than can pass during one phase. • All vehicles potentially participating in the group can securely communicate with each other. • Centralised: all vehicles potentially participating in the group can establish a secure connection with the appropriate traffic control centre. • Centralised: there is one dedicated traffic control centre for the given intersection.
Geographic Scope	Regional.
Illustrations	

Pre-Conditions	• Intersections benefiting from the Use Case need to be known to the initiating HVs (e.g. through prior communication or updates). • The traffic control centre provides advice to the vehicles on how to approach the intersection and which path to take there (lane, relative position or absolute position). • The vehicles arrive at the intersection and wait at a red light.
Main Event Flow	Centralised solution, Use Case driven by the traffic control centre. Phase 1 (group formation by the traffic control centre with communication channelled through it alone): • The traffic control centre announces the formation of a group of vehicles to perform a group start. • The traffic control centre assigns the leadership role to leading vehicles in the group. • The traffic control centre announces the final group properties (e.g. planned manoeuvre and trajectory, including acceleration, yaw rate, etc.) and requests an acknowledgement from each vehicle which has the ability to opt out of the formed group. • If needed, the traffic control centre updates the group according to the final acknowledgements. Phase 2 (manoeuvre selection and initiation): • The lead vehicle performs additional double checks to verify that the traffic light information is correct (e.g. cross-checking locally available information with that from the traffic control centre) and the environment is ready for the group start the manoeuvre. • The lead vehicle initiates the manoeuvre through a message to all group participants. • From this point on the group is considered as 'closed' and communicates within the group only (communication within the group is confidential/encrypted); there is no communication between different groups. • To the outside world, the lead vehicle announces the intent, position, and progress of the platoon (e.g. similar to a CAM type message). • All vehicles send updates and additional information (e.g. detour or delay due to pedestrians) to the lead vehicle. • To the infrastructure and the traffic control centre, the lead vehicle stays in contact to report the platoon's progress. Phase 3 (manoeuvre monitoring and update): • While executing the manoeuvre, the vehicles constantly monitor the environment; the lead vehicle takes a special role by monitoring ahead for any obstacles. • All manoeuvre changes are announced by the lead vehicle. Phase 4 (group release): • The lead vehicle terminates the group start manoeuvre o Successful: all vehicles have completed the intended path of the 'group start' platoon

<table>
<tr><td></td><td>
<li style="list-style:none">
Unsuccessful: at least one vehicle has not yet completed the intended path within a given time

The lead vehicle communicates that the group is dissolved unsuccessfully
The lead vehicle also includes the most recent signal phase and timing information in that message

The lead vehicle provides a report of the group start manoeuvre to the traffic control centre.

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<tr><td>Alternative Event Flow</td><td>
Decentralised solution, Use Case driven by the HV.

Phase 1 (group formation by the HV):

The HV announces the formation of a group of vehicles to perform a group start.
The RVs decide, depending on their route, if partaking in the group is of benefit to them and accept/decline.
The lead vehicle performs checks to verify that the traffic light information is correct (e.g. cross-checking locally available information with that from RVs) and updates the RVs.

Phase 2 (final group and manoeuvre selection and initiation):

The HV announces group leads and the trajectory (e.g. planned manoeuvre and trajectory, including acceleration, yaw rate, etc.); leads are selected based on the information gathered in Phase 1 by the HV.
From this point on, the different groups are considered as closed and communicate within the group only (communication within the group will be confidential (encrypted); there is no communication between different groups.
The group lead initiates the manoeuvre through a message to all group participants and the environment is ready for the group start manoeuvre.
To the outside world, the group lead announces the intent, position, and progress of the platoon (e.g. similar to a CAM type message).
All vehicles send updates and additional information (e.g. detour or delay due to pedestrians) to the group lead.

Phase 3 (manoeuvre monitoring and update):

While executing the manoeuvre, the vehicles constantly monitor the environment; the group lead takes a special role by monitoring ahead for any obstacles.
All manoeuvre changes are announced by the lead vehicle,

Phase 4 (group release):

The group lead terminates the group start manoeuvre

Successful: all vehicles have completed the intended path of the ‘group start’ platoon
Unsuccessful: at least one vehicle has not yet completed the intended path within a given time

</td></tr>
</table>

	▪ The lead vehicle communicates that the group is dissolved unsuccessfully ▪ The lead vehicle also includes the most recent signal phase and timing information in that message
Post-Conditions	All vehicles have completed the manoeuvre or the green phase ends.
Information Requirements	• Signal phase and timing information. • Properties of the group. • Position. • Speed. • Acceleration. • Yaw rate. • Planned path. • Timeout after which the manoeuvre is considered as unsuccessful.

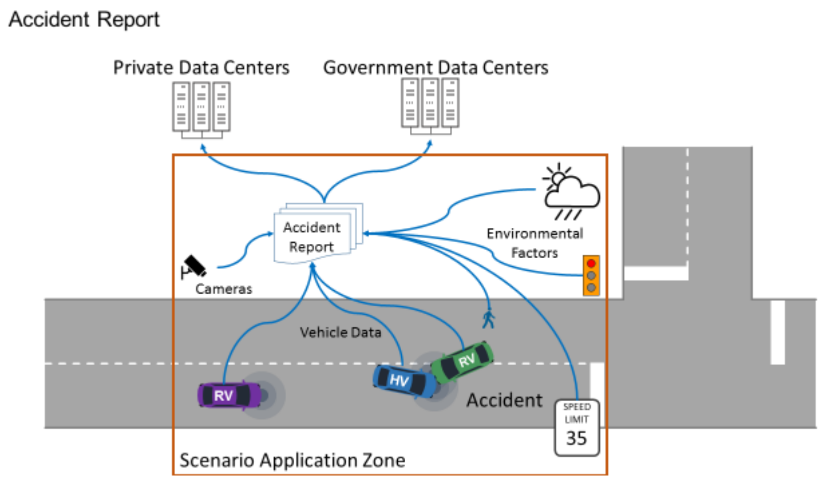
User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	150 1500	Assuming that a vehicle (including inter-vehicle) gap is 15 m, and 10 vehicles within the group, the result is 150 m between vehicles, and 300 m between vehicle and roadside infrastructure. For a centralised solution and for correct location assignment, distances between vehicle and manoeuvre control unit needs to be larger.
Information Requested/Generated	Quality of information/ Information needs	300 bytes (every 50 ms/20 Hz per participating vehicle)	The majority of the packages are expected to be status update reports (e.g. position, acceleration, yaw rate, etc.). Hence, the size of the messages are expected to be similar to a basic safety message (about 300 bytes).
Service Level Latency	[ms]	10	10 ms of Service Level Latency for communications between the members of the group. This is based on the very low distances (e.g. inter-vehicle = 20 cm) between vehicles waiting at the red light during the start manoeuvre.
Service Level Reliability	%	99.999	Corresponds to the high probability of this Use Case being successfully applied. A tolerable packet error rate on the lower layers is considered to be 99%.

Velocity	[m/s]	70 km/h, 19.4 m/s	Assumes the usual speed in cities reached by the end of the manoeuvre.
Vehicle Density	[vehicle/km^2]	3200	Assumes at one intersection that there are 80 vehicles (e.g. 8 lanes considering different directions and 10 vehicles in each lane). Further assuming that there are up to 40 intersections per km^2 (e.g. in Manhattan), it results in 3200 vehicles/km^2 as an upper bound.
Positioning	[m]	0.2 (3σ)	Required for low inter-vehicle distance.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Use Case considered possible between different brands/makers. Regulatory oversight for safety related questions is needed. Standardisation on the application layer (message set and flow control) is desirable.

5.7 Society and Community

5.7.1 Accident Report

Use Case Name	**Accident Report**
User Story	When host vehicles are involved in an incident, an accident report containing a time-windowed recording of vehicle systems data, rich sensory information, environmental conditions and any available camera views is sent to government and private data centres.
Category	Society and community.
Road Environment	Urban, rural, highway.
Short Description	Host vehicles send an accident report to government and private data centres.
Actors	Host vehicles, remote vehicles.
Vehicle Roles	HVs represents vehicles involved in the accident. RVs represent neighbouring vehicles.
Roadside Infrastructure Roles	Signs and traffic signals provide dynamic environmental input to the accident report.
Application Server Roles	Not applicable.
Other Actors' Roles	• OEM and government data centres are receiving the reports. • Vulnerable road users provide dynamic environmental input to the report. • Weather and road conditions provide environmental input to the report.

	• Surveillance cameras provide a capture video recording of the accident.
Goal	Sends accident reports to OEMs, government and insurance data centres.
Needs	HV needs to send an accident report containing a time-windowed recording of vehicle systems data, rich sensory information and dynamic environmental conditions to OEM and government/insurance data centres.
Constraints/ Presumptions	• Assumptions will be required for the following information ○ Extent of scenario application zone • Parties involved have agreed to sharing information and reporting in the event of a collision. • Capturing data recordings needs to adhere to regulatory rules where applicable.
Geographic Scope	Global.
Illustrations	
Pre-Conditions	The 'accident report' scenario is enacted when one or more HV's are involved in an accident.
Main Event Flow	If the 'accident report' scenario is enacted when: • Locations and dynamics are collected from HVs. • Vehicle system data recordings are collected from HVs. • Locations and dynamics are collected from RVs in the scenario application zone. • Dynamic environmental data are collected from sources in the scenario application zone. • Video recording are collected from cameras in the scenario application zone. • An accident report is sent to appropriate data centres.
Post-Conditions	Accident report is sent to appropriate data centres.

Information Requirements	• Accident report includes a captured time window of
	  ○ Position and dynamics of HVs
	  ○ Vehicle system data of HVs
	  ○ Video from nearby cameras
	• Environmental data including
	  ○ Position and dynamics of RVs

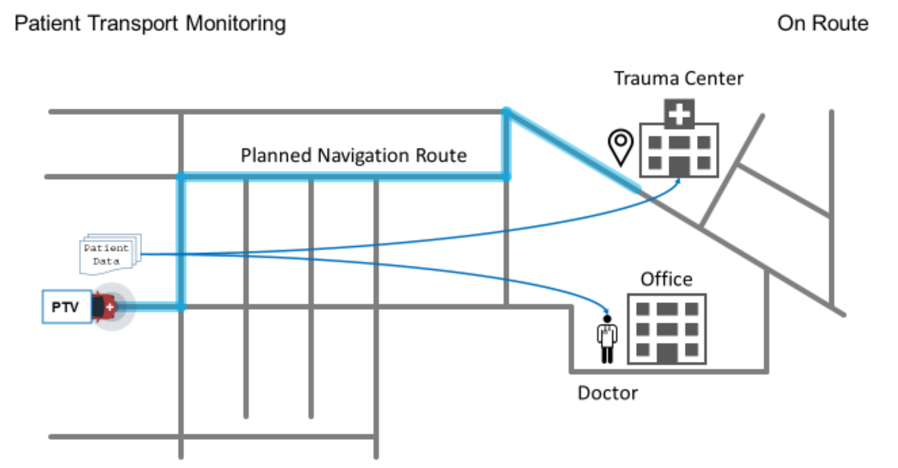
	○ Position and dynamics of vulnerable road users ○ Position, nature and state of traffic signals, signs, etc. • Weather and road conditions

User Story	Detailed description and specifics
User Story #1	A host vehicle rear-ended a remote vehicle while another HV was pulling out of a parking spot on a crowded downtown street.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Data centres can be anywhere in the network.
Information Requested/Generated	Quality of information/ Information needs	1000-1500 byte packets Large files containing sensor data prior to and after the collision	30 seconds of BSM (CAN)-type data for each vehicle (~75 KB/vehicle). 60 seconds of at least two cameras (8 Mbps/camera). In total 120 MB video data + 15 MB CAN Data in 10 minutes result in a data rate of 1.8 Mbps. HD map of the street section prior to the crash.
Service Level Latency	[ms]	N/A	Data is not time critical.
Service Level Reliability	%	High / 99.99	Data needs to be transferred reliably.
Velocity	[m/s]	0	Both vehicles are at full stop.
Vehicle Density	[vehicle/km^2]	12,000	Maximum assumed density in urban environments.
Positioning	[m]	1.5 (3σ)	Required for the precise reconstruction of the accident.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability is needed between HV, RVs, traffic lights, surrounding video cameras and data centres. Regulation: Yes Standardisation: Yes

5.7.2 Patient Transport Monitoring

Use Case Name	Patient Transport Monitoring

User Story	Paramedics, patient monitoring equipment, trauma centres and doctors share vital patient telemetry data, images, voice and video during patient transport.
Category	Society and community.
Road Environment	Urban, rural, highway.
Short Description	Patient transport vehicle (PTV) shares patient telemetry data, images, voice and video between paramedics, hospitals and doctors.
Actors	Patient transport vehicle.
Vehicle Roles	PTV represents the vehicle that is transporting a patient.
Roadside Infrastructure Roles	Not applicable.
Application Server Roles	Not applicable.
Other Actors' Roles	Not applicable.
Goal	Shares patient telemetry data, images, voice and video with paramedics, trauma centres and doctors during patient transport.
Needs	Paramedics, trauma centres and doctors need to share patient telemetry data, images, voice and video during patient transport.
Constraints/ Presumptions	Not applicable.
Geographic Scope	Global.
Illustrations	

Pre-Conditions	• The 'en route' scenario is enacted when
	  ○ The patient is in the PTV
	  ○ The patient is being monitored
	  ○ The destination trauma centre is identified
	• The assigned doctor(s) are identified.

Main Event Flow	• If the 'en route' scenario is enacted

	○ PTV streams patient telemetry data to the trauma centre and doctor(s) ○ If requested, PTV sends images to trauma centre and doctor(s) ○ If requested, PTV establishes an audio call between paramedics, trauma centre and doctor(s) ○ If requested, PTV establishes a video call between paramedics, trauma centre and doctor(s)
Post-Conditions	PTV is sharing patient telemetry data, images, voice and video between paramedics, hospitals and doctors while en route.
Information Requirements	• PTV's location and dynamics. • Patient information. • Destination trauma centre. • Assigned doctor(s). • Navigation route. • Patient telemetry data (health monitoring). • Voice call. • Video call. • Images.

User Story	**Detailed description and specifics**
User Story #1	Patient transport vehicle is moving at 100 km/h on a crowded downtown street towards an emergency room.

User Story #1			
Service Level Requirement	**SLR Unit**	**SLR Value**	**Explanations/Reasoning/Background**
Range	[m]	N/A	Assumes that the emergency room could be arbitrarily far from the EV, which yields a N/A value. It should be noted that the EV might exchange information (e.g. patient's condition) with a virtual emergency room.
Information Requested/Generated	Quality of information/ Information needs	Mix of video streaming, two-way voice and data	8 Mbps video data rate. 64 Kbps voice data rate. 1 Mbps for monitoring of patient. (e.g. patient's vital signs are measured onboard the vehicle and sent to the hospital physicians for real-time monitoring and later review; such data may include 3, 5 and 12 lead ECG, SpO2, plethysmogram, respiration, skin temperature and continuous non-invasive blood pressure).
Service Level Latency	[ms]	150	Voice and video streaming, real-time data.

Service Level Reliability	%	99 video and voice 99.999 for data	Some errors in video and audio are acceptable.
Velocity	[m/s]	30	Assuming speeds up to 100 km/h.
Vehicle Density	[vehicle/km^2]	12,000	Maximum assumed density in urban situation.
Positioning	[m]	N/A	Positioning accuracy is not critical for this Use Case.
Interoperability/ Regulatory/ Standardisation Required	[yes/no]	Yes/Yes/Yes	Interoperability (from the ambulance to the application server): Yes Regulatory for data protection issues: Yes Standardisation: Yes

6 Conclusions and Next Steps

The present documents contains the second set of advanced Use Case descriptions (previously referred to as 'WAVE 2') developed in 5GAA WG1. This second set completes the goals and objectives of the 5GAA WG1 work item 'Use Case and KPI requirements' [1]. One of the goals of these UC descriptions is to provide the possibility to derive requirements for 5G networks.

The results of this report, and of the future Use Case descriptions and related communication requirements, are intended to serve as input for the work of other WGs in 5GAA, as well as sources for input and feedback to standardisation activities, e.g. in 3GPP.

5GAA

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