5GMOBIX

5G for cooperative & connected automated MOBIlity on X-border corridors

D2.1

5G-enabled CCAM use cases specifications

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ABBREVIATIONS

Abbreviation	Definition
AD	Autonomous/Automated Driving
5G NR	5G New Radio
5G-PPP	5G Infrastructure Public Private Partnership
ADAS	Advanced Driver Assistance System
AI	Artificial Intelligence
AV	Automated Vehicle
BS	Base Station
CAD	Connected and Automated Driving
CAM	Connected and Automated Mobility
CAN	Controller Area Network
CAV	Connected and Automated Vehicle
CBC	Cross Border Corridor
CCAM	Cooperative, Connected and Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
CN	China
CPE	Collective Perception of Environment
CPM	Collective Perception Message
C-RAN	Cloud-Radio Access Network
DE	Germany
DoA	Description of Action
DSRC	Dedicated short-range communications
EC	European Commission
ECU	Electronical Control Unit
EDM	Edge Dynamic Map

eMBB	enhanced Mobile Broadband
ES	Spain
EU	European Union
EV	Electronic Vehicle
FCD	Floating Car Data
FI	Finland
GA	General Assembly
GPRS	General Packet Radio Service
GPS	Global Positioning System
GR	Greece
HAD	Highly Automated Driving
HD	High Definition
HW	Hardware
ITS	Intelligent transport system
KPI	Key Performance Indicator
KR	Korea
L4	Level 4
LDM	Local Dynamic Map
LTE	Long-Term Evolution
MEC	Multi-access/Mobile Edge Computing
MIMO	multiple-input and multiple-output
ML	Machine Learning
mMTC	massive Machine Type Communications
MNO	Mobile Network Operator
NFV	Network function virtualization
NL	Netherlands

OBU	On Board Unit
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PLMN	Public Land Mobile Network
PT	Portugal
RAN	Radio Access Network
RDV	Remote Driving Vehicle
RSU	Road Side unit
SAE	Society of Automotive Engineers
SDA	Strategic Deployment Agenda
SDN	Software-defined networking
SIM	Subscriber Identity Module
SW	Software
TR	Turkey
TS	Technical Specification
UC	Use Case
UCC	Use Case Category
UE	User Equipment
UHD	Ultra-high-definition
URLLC	Ultra-Reliable Low Latency Communications
US	User Story
V2X	Vehicle to Everything
VRU	Vulnerable Road User
WP	Work Package
X-border	Cross-border

EXECUTIVE SUMMARY

This document is the deliverable D2.1 "5G-enabled CCAM use cases specifications". The main objective of the deliverable is to provide a detailed description of the 5G-MOBIX use cases. The use cases are classified into 5 categories (Advanced Driving, Platooning, Extended Sensors, Remote Driving and Vehicle quality of Service Support) and distributed among two cross-border corridors (Greece-Turkey and Spain-Portugal) and six local sites in France, Germany, Netherlands, Finland, China and South Korea. These are different corridors and trial sites in several domains and perspectives, enriching the project trials considering the distinct characteristics of each one. All these trials will address a set of complementary and diverse use cases of CCAM systems.

The 29 signatory countries of a Letter of Intent[1] signed at Digital Day 2017 agreed to designate 5G cross-border corridors, where vehicles can physically move across borders and where the cross-border road safety, data access, data quality and liability, connectivity and digital technologies can be tested and demonstrated. 5G-MOBIX is aligned with the European Commission's ambition to focus on these corridors in CCAM use cases. The two cross-border corridors (Greece-Turkey and Spain-Portugal) that are part of 5G-MOBIX are the two pillars of the project and references for the rest of the local trial sites, providing a major contribution for the future large scale 5G deployments in the context of CEF 2 package. The use cases present at local sites contribute to the cross-border corridors in diverse ways. The concrete contributions are described for each local site use case.

The rest of the document is organised as follows:

- **Section 1, Introduction,** presents 5G-MOBIX, the purpose of the document and its intended audience.
- **Section 2, Cross-Border Issue Analysis,** describes the classification into categories of different issues present at the cross-border areas when operating advanced CCAM applications. In addition, an initial set of issues is introduced for each category.
- **Section 3** describes the trial sites of **5G-MOBIX Cross-Border Corridors** (CBC).
- **Section 4, 5G-MOBIX Use Case Categories**, explains the methodology for use case classification and the use case categories are listed.
- **Sections 5-9,** describe the **5G-MOBIX Use Cases and User Stories**, pointing the addressed cross-border issues. In the case of user stories implemented at local sites, their significance and uniqueness are justified and a portfolio of assets that could be transferred to cross-border corridors is also defined.
- **Section 10** gives an **overview of the use cases**, showing their complementarity and alignment with EC's vision.
- **Section 11** presents the **conclusions.**

[1] http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=43821

1. INTRODUCTION

1.1. 5G-MOBIX concept and approach

5G-MOBIX aims to showcase the added value of 5G technology for advanced Cooperative, Connected and Automated Mobility (CCAM) use cases and validate the viability of the technology to bring automated driving to the next level of vehicle automation (SAE L4 and above). To do this, 5G-MOBIX will demonstrate the potential of different 5G features on real European roads and highways and create and use sustainable business models to develop 5G corridors. 5G-MOBIX will also utilize and upgrade existing key assets (infrastructure, vehicles, components) and the smooth operation and co-existence of 5G within a heterogeneous environment comprised of multiple incumbent technologies such as ITS-G5 and C-V2X.

5G-MOBIX will execute CCAM trials along cross-border (x-border) using 5G core technological innovations to qualify the 5G infrastructure and evaluate its benefits in the CCAM context. Aligned to identified cross-border issues, the Project will also exercise a set of user stories executed at inland corridors that would bring new telecom, application security, privacy or regulatory issues outside the ones considered at the cross-border corridors.

5G-MOBIX will first analyse the general telecom, application, security, data privacy and regulatory issues present at the cross-border corridors.

From there, 5G-MOBIX declares a set of advanced CCAM use cases stressed at cross-border areas needing advanced connectivity provided by 5G, and the required features to be enabled to meet the identified issues. These advanced CCAM use cases and the specific features and technologies of 5G networks will be mainly tested across the trials on 5G corridors in different EU countries as well as in Turkey, China and Korea. A set of complementary user stories will focus on different telecommunication infrastructures, perform data computation in different communication sides, apply different connectivity models across the actors or stress a specific 5G platform tier, while they propose solutions still valid for issues applicable in cross-border areas, but not covered in the cross-border evaluation sites, expanding the project results.

The trials will also allow 5G-MOBIX to conduct evaluations and impact assessments and to define business impacts and cost/benefit analysis. As a result of these evaluations and international consultations with the public and industry stakeholders, 5G-MOBIX will identify new business opportunities for the 5G enabled CCAM and propose recommendations and options for its deployment.

Through its findings on technical requirements and operational conditions 5G-MOBIX is expected to actively contribute to standardisation and spectrum allocation activities.

1.2. Purpose of the deliverable

The present document is the second delivered version of D2.1 "5G-enabled CCAM use cases specifications", which is part of WP2. The overall purpose of the document is to define the 5G-MOBIX use cases and serve as a reference to design the development, deployment and test of the 5G-MOBIX use cases. This updated version of D2.1 includes an overview of general telecom, application, security, data privacy and regulatory issues or technical challenges present at cross-border areas (page 22). Then, some challenging use cases are proposed to address these issues (page 40). The focus of 5G-MOBIX is on the cross-border corridors, therefore in addition to addressing different technical challenges and having complementary user stories, the local trial sites also contribute to cross-border corridors with tangible assets. This document gives a high-level overview of the initial proposal of contributions to cross-border corridors. More detail will be given in WP3 and WP4 deliverables.

The present deliverable directly feeds the other 5 deliverables that are part of Work Package 2 (WP2):

- D2.2 "5G architecture and technologies for CCAM specifications". This deliverable describes the reference 5G architecture and the dedicated 5G technologies relating to the deployment of advanced CCAM use cases.
- D2.3 "Specification of the infrastructure for 5G augmented CCAM". This deliverable specifies the architecture and the components, as well as their interaction with the vehicle to execute the CCAM use cases.
- D2.4 "5G augmented vehicle specifications". This deliverable provides the detailed specification of vehicle enhancement using enhanced 5G connectivity for implementing the advanced CCAM use cases
- D2.5 "Initial evaluation KPIs and metrics". This deliverable presents the initial KPIs and relevant metrics to be used for the evaluation, including those resulting from the specification activities.
- D2.6 "Final set of 5G/CCAM systems and vehicle specifications". The Final set of 5G/CCAM systems and vehicle specifications will collect all the final agreed specifications.

The first four deliverables, D2.2-D2-5, are delivered at the same time than the current version of this deliverable. D2.6 will be delivered at month 30. The overlap between D2.1 and the rest of WP2 deliverables has been minimised as much as possible. Therefore, this deliverable does not include any detailed description of system architectures, 5G infrastructures, test vehicles, KPIs or requirements.

1.3. Intended audience

The dissemination level of D2.1 is public (PU) and is meant primarily for (a) all members of the 5G-MOBIX project consortium, and (b) the European Commission (EC) services.

This document is intended to serve as an internal guideline and reference for all 5G-MOBIX beneficiaries, especially the trial site leaders.

2. CROSS-BORDER ISSUE ANALYSIS

2.1. Methodology for issue analysis and classification

The cross-border corridors bring a challenging environment where different issues for connected and automated mobility must be addressed to ensure a timely, continuous and seamless operation of a CCAM application. Specifically, different members laws, actors, industries, operators and economies take place at the EU bridged by a common transit regulation. Thus, the cross-border corridors become salient areas to promote integration and interoperability concentrating public and private resources. Digital Single Market aims to overcome these challenges.

According to the 5G-MOBIX vision, different components meet at the cross-border areas when operating CCAM applications. Each of these components has its own issues or challenges to solve including technological and business aspects. The core idea behind the methodology is that 5G-MOBIX will show the impact of the proposed use cases when evaluated at specific 5G corridors to the identified issues. Each 5G corridor, deployed in a cross-border evaluation site or a trial evaluation site will have a complementary focus on specific issues present at cross-border areas. This means that use cases tested at evaluation trial sites overcomes issues present at cross-border areas but out of the scope of the evaluation performed at cross-border evaluation sites.

Specifically, the considered issues pivot around four main orthogonal dimensions for all the use cases at the cross-border corridors:

1. Telecommunications including 5G infrastructures operating 5G technologies to process or connect AD functions from the use cases enabled by core technological innovation from 5G, such as new frequency bands, Cloud Radio Access Network (C-RAN), Mobile Edge Computing and network virtualisation infrastructures.

2. Application executing the CCAM service on a vehicle or a set of them along a cross border context which may include several operator's domains and business models.

3. Security and privacy spanning the communication and application threats at cross border kind of roads, mainly highways.

4. Regulation encompassing communications, application and security and privacy concerns.

To double check that the issue ecosystem from 5G-MOBIX is consistent, complementary, solid and relevant the following methodology has been implemented. First, the Technical Coordinator has identified the issue categories and has circulated among a committee with representative 5G, vehicle OBU and RSU experts from the consortium to analyse the completeness of the categories and the applicable issues inside each category. This activity has been led by WP4.

To cover all the different angles from stakeholders with similar structure and details, the experts follows a template. Thus, each expert has produced contributions formatted to ease the generalization of responses to merge issues under abstract definitions. Specifically, these fields have been evaluated for each proposed issue inside each category:

- Conditions and Environment from specific use case category perspective.
- Consequences and Impacts from specific use case category perspective.
- Solutions and Alternatives from a technological perspective.

Use cases categories considered in 5G-MOBIX are mapped to issues involved in the following sections. 5G-MOBIX has to impact cross border 5G deployments enabling CCAM along 5G corridors potentially including several operator's domains. Thus, the identification of a cross-border trial site with valid environment, in terms of driving situations and 5G features to exercise the use case is essential.

To maximize the efficiency of the project activities, developments and deployments, solutions to essential issues will be tested by user stories evaluated at cross border trial sites, as progressed as more promising by the CBC experts, while other relevant issues will be tested at evaluation trial sites, to offer a complete and well-rounded evaluation. These evaluation trial sites provide an alternative and more controlled setup producing valuable information, techniques, settings and technologies to overcome issues also present at the cross-border trial sites adding some differential value. Furthermore, trial site environments must supply a cross-border equivalent environment with potential handover and roaming connectivity implications where the dynamics and timeline of the evaluated user stories must have sense in a cross-border corridor environment potentially including several operator's domains.

Once the first review of all those issues have been performed by all the members of the experts' committee, the results have been reported to use case category leaders and trial site leaders to invite them to clearly identify the issue(s) to be addressed and evaluated at the trial sites. This action has been led by WP2.

A second iteration detects overlaps with similar contributions. Different trial sites can target the same use case category, but each user story needs to add some differential value in terms of issues met. Overlapped contributions have been removed to make each contribution unique coming from the evaluation of a use case in a specific cross-border site or trial site.

Figure 1 depicts the review work flow.

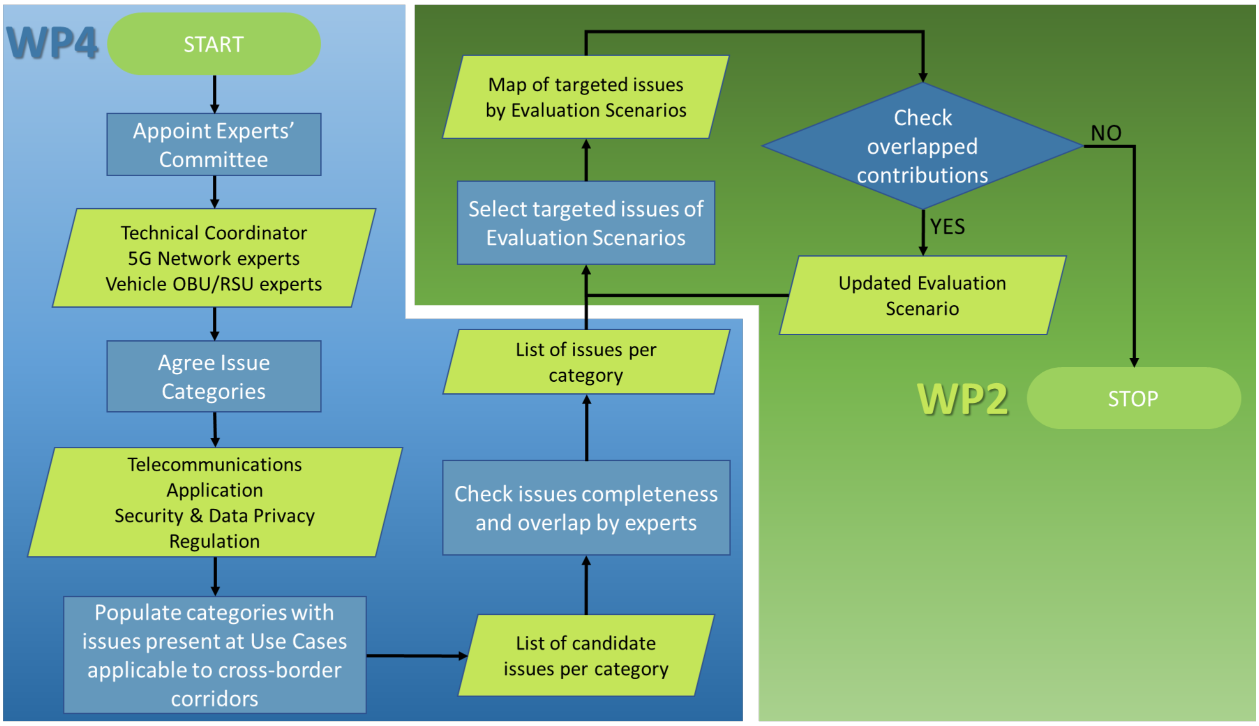

Figure 1 Use Case review workflow.

Once the methodology to formulate the issues present at cross-border corridors and align them to the selected use cases by 5G-MOBIX has been described, the issues are listed below. In the next sections it is detailed the pilot site which will host the use case deployment and demonstration meeting specific issues.

2.2. Issues at cross-border corridors

The different cross-border issues categories are:

1. Telecommunications
2. Application
3. Security & Data Privacy
4. Regulation

The following sections compiles the identified issues present at cross border corridors for each category.

2.2.1. Telecommunications

The identified telecommunications issues are summarized in Table 1. A more detailed analysis per issue, as well as the potential solutions to alleviate / mitigate this problem are discussed in D2.2.

Table 1 Issues list for Telecommunications category

ID	Issue name	Short description
TR1	NSA *Roaming* Latency	Slow switching from an NSA network domain to another NSA network domain
TR2	SA *Roaming* Latency	Slow switching from a SA network domain to another SA network domain
TR3	Hybrid *Roaming* Latency	Slow switching between NSA and SA network domains
TH1	Hybrid *Handover* Latency	Slow transition between serving 4G eNB and 5G gNB when UE moves
TH2	Low coverage *Handover*	Partial coverage with grey areas with low coverage and QoS/SLA
TH3	Overlap coverage *Handover*	Unsteady handover due to overlapped coverage of dense RAN infrastructures produce
TC1	*Continuity* Protocol	The handover or roaming actions affect to the continuity of any protocol of the service stack such as IP address change
TC2	Performance *Continuity*	Variable upcoming traffic produce congestion at the network not accommodated dynamically without live resource allocation/provisioning
TN1	Geo-*Networking* IP	Inefficient networking ignoring geo-position of UEs when transmitting packets also for multicast or broadcast modes
TN2	Hybrid *Networking*	Device isolation requiring new network functions to provide access to internet to IP traffic coming from other wireless or wired technologies
TN3	Geo *Networking* Overhead	Geo header contains a lot of overhead, which is not needed when transmitting over Uu (TCP/IP)
TN4	Inter-MEC Connectivity	Zero latency from MEC services is missing when a UE moves to other cell and the surrounding MECs need to exchange data though a cloud node instead of directly connected

TS1	Service & device isolation	Irregular service performance depending on the wireless technology concurrency level, utilized frequency and service demands
TS2	Edge Service lifecycle	Availability of APIs to third party to supply Edge as an Infrastructure Provider
TS3	Multicast Share	Ability to establish multicast communications, not only unicast

Figure 2 depicts the different issues identified.

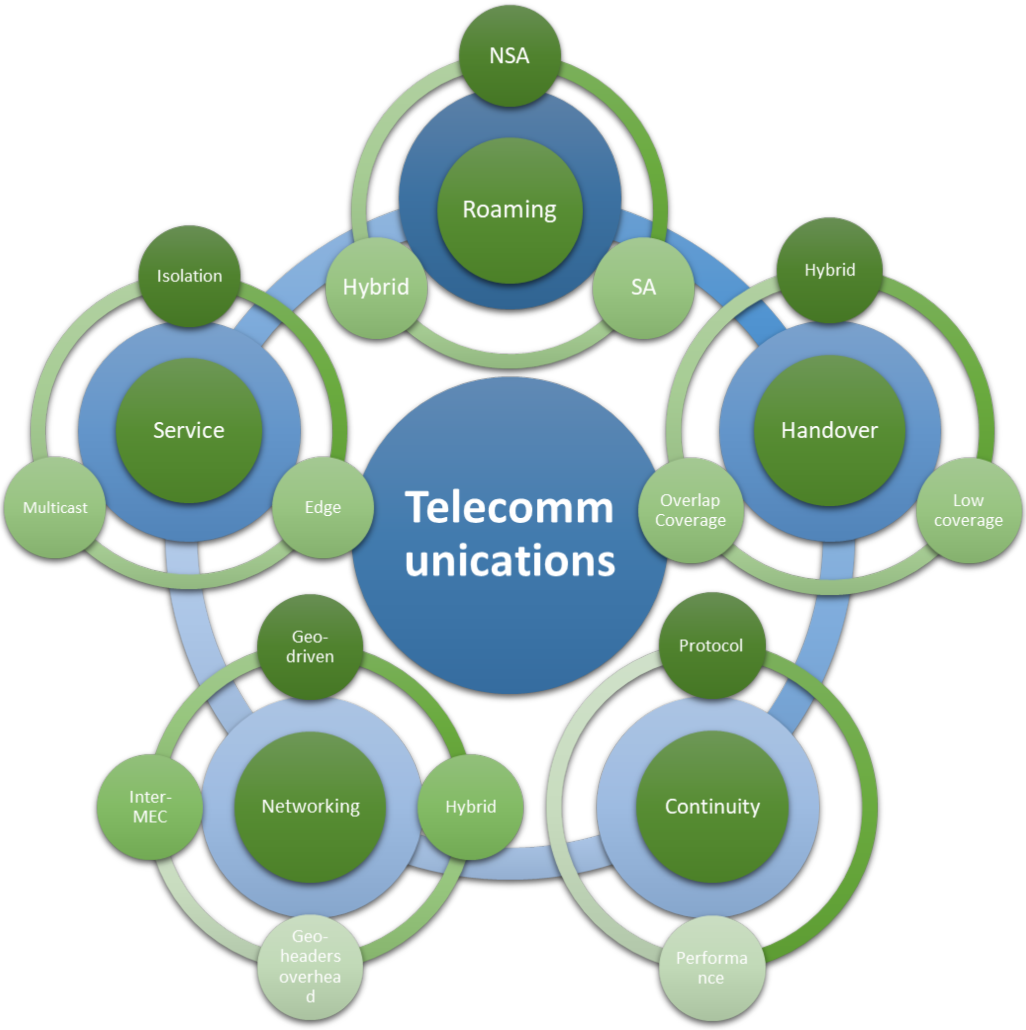

Figure 2 Telecommunications issues summary.

2.2.2. Application

The identified application issues are summarized in Table 2. A more detailed analysis per issue, as well as the potential solutions to alleviate / mitigate this problem are discussed in D2.3.

Table 2 Issues list for Application category

ID	Issue name	Short description
AC1	V2X Continuity	Unsteady communications performance among vehicles, servers and network functions
AC2	Dynamic QoS *C*ontinuity	Unsteady connectivity and changeable performance depending on network concurrency when no management of multi-resolution data
AI1	Data *I*nteroperability	Inconsistent data schemas exchanged across vehicles vendors, network domains, infrastructure systems or federated service servers
AI2	Stack *I*nteroperability	Inconsistent vehicle, edge or cloud Protocols/APIs across different technology vendors and network domains
AI3	Time *I*nteroperability	Inconsistent time zones management for synchronous actions with common timeline
AG1	Accurate Geo-Positioning	Vehicles are relying heavily on positioning. GPS positioning accuracy is not enough.
AG2	Geo-driven Discovery	Inefficient indexing of vehicles and attachment of data when ignoring geo-position of UEs
AP1	Real-time Multi-tier *P*rocessing	Data inconsistency when are live fused by AD functions hosted in different actors, the onboard sensor processors, the processed data at RSUs, the coordination data from the MEC service and the management data from the central service
AP2	On-demand *P*rocessing	Lack of computing scalability to process the incoming volume of data with different speed and density producing bottlenecks and delays

Figure 3 depicts the different issues identified.

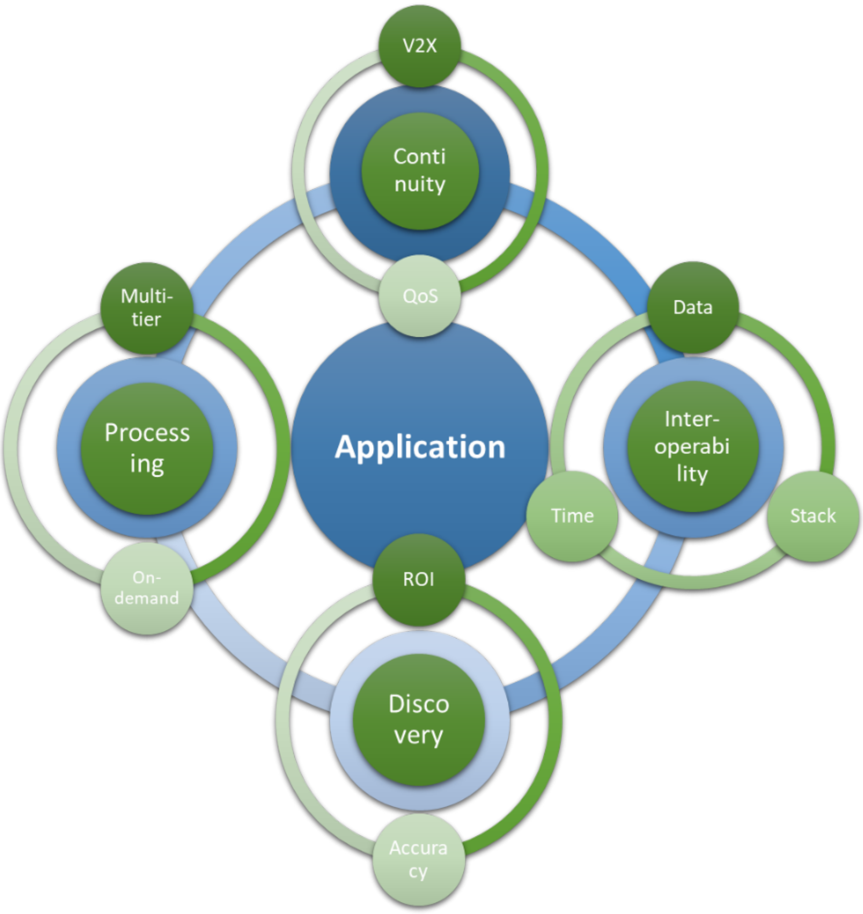

Figure 3 Application issues summary.

2.2.3. Security & data Privacy

The cross-border issues, presented in Table 3, possess many aspects that are generalised in Table 4. The later will be developed in other 5G-MOBIX deliverables:

- GDPR and data protection in Telecommunication and other aspects such as lawful intercept and NIS directive are addressed in D2.2,
- Trusted and secure communications is addressed in D2.3,
- Data processing in CCAM under different data protection regulations is addressed in D2.4.

Table 3 Issues list for Security & data Privacy category

ID	Issue name	Short description
ST1	Federation *Trust*	New components and infrastructures need a trust model and certificate policy to be aggregated. Surrounding road elements are not officially aggregated to be part of the road infrastructure. They can be part of a hacking environment (traffic signs or emulated presence)
ST2	Discovery *Trust*	Surrounding vehicles cannot be directly trusted to exchange data (V2V, V2N, V2I)
SP1	Data *Privacy*	Traffic management systems and distributed processing by cloud or MEC services are not able to deal with E2E Encrypted dataflows
SP2	Anonym *Privacy*	Anonymization techniques are not applied when storing persistent data (non-real time) of the service and live data from sensors (real time)
SO1	Data *Ownership*	When data is stored instead of doing a pure live processing of incoming data, they have an owner which can apply limited purpose or time utilization when transferred

Cybersecurity mechanisms should be implemented in order to protect the entities of the 5G-MOBIX reference architecture described in the D2.3: the cloud, network (5G networks and the others) and the vehicles infrastructures. These mechanisms based on standards and others technical reports from ENISA and different SDOs (*e.g.* ETSI, IETF), even though not directly identified as *cross-border issues* and should be considered from the specification to the roll-out of the CCAM infrastructures. These mechanisms serve also to protect the solutions to the other cross-border issues categories and will be described accordingly in deliverables mentioned above.

Aspects related to ORDP and IPR (Data ownership) are addressed in the Data management plan (D1.4) as described here: *"The ORD pilot aims to improve and maximise access to and re-use of research data generated by Horizon 2020 projects and takes into account the need to balance openness and protection of scientific information, commercialisation and Intellectual Property Rights (IPR), privacy concerns, security as well as data management and preservation questions."*

Table 4 Generalisation of Issues list for Security & Data Privacy category

Id	Issue name	Short description
STS1	Trusted and secure communications between vehicles from different trust domains	Without a common trust domain between the EU, Turkey, Korea and China, trusted and secure communication between the vehicles could not be achieved when the vehicles from different trust domains are to communicate. This is the general case of ST1 and ST2.
SDP0	Personal data processing under different data protection regulations	Different data protection regulations apply when processing personal data of data subject in Europe, Turkey, China and Korea. Therefore, many legal, organisational and technical challenges need to be overcome for lawful processing of this data. This is the general case of SP1 and SP2.
SDP1	Legal	Without proper legal basis, lawful processing of personal data could not be achieved. Indeed, legal issues arise at the enforcement of the GDPR to CCAM. For example, CAM and DENM messages (and other CCAM messages) are considered personal data but are required for the normal functioning of the CCAM systems.
SDP2	Organisational	Partners in 5G-MOBIX processing data from citizen of different countries needs to put proper organisational procedures to handle data protection. These includes (but not limited to) Data processing cartography, Training, Privacy risk assessment, Privacy impact assessments, Data breach procedures, Documentation.
SDP3	Technical	The technical mechanisms that are applied in order to support the legal requirements on lawful data processing could find difficulties in a cross-border scenario. These mechanisms include (but are not limited to)[2]: Data encryption, Data minimization, Anonymization,

[2] These mechanisms should be implemented in the appropriate entities of the 5G-MOBIX reference CCAM architecture described in D2.3 and should to be adapted for each 5G-MOBIX partner.

		Differential privacy mechanism, Informed consent, Privacy by design and by default, Secure programming and Assessment of these techniques themselves.

Figure 4 depicts the different issues identified.

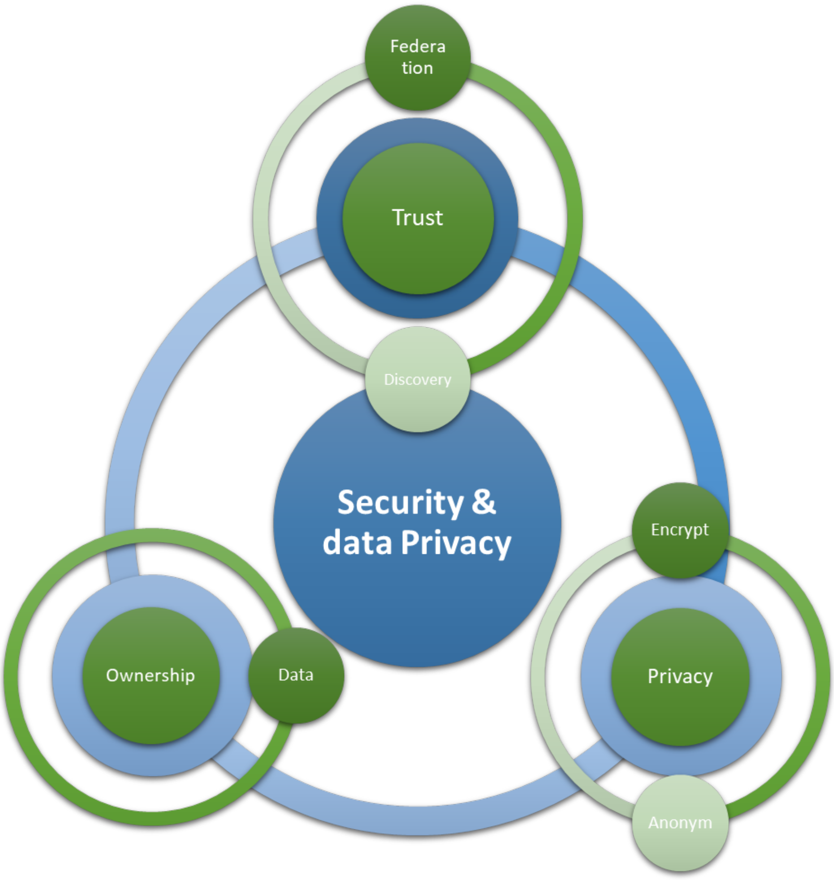

Figure 4 Security & data Privacy issues summary.

2.2.4. Regulation

The identified telecommunications issues are summarized in Table 5. A more detailed analysis per issue, as well as the potential solutions to alleviate / mitigate this problem are discussed in D2.5.

Table 5 Issues list for Regulation category

ID	Issue name	Short description
RC1	Autonomous Vehicle regulation Compliance	GDPR and homologated systems for ADAS are properly implemented and applied, also to support difficulties of identifying AVs from Non-AVs on roads
RC2	Road & traffic regulation Compliance	Traffic signs and rules have a different regulation requiring different computer vision training or application of different operative limits to vehicles' dynamics
RC3	Sensor Compliance	Heterogeneous homologation of sensors
RG1	Geo-dependant spectrum	Neighbouring countries can have different radiofrequency spectrum
RL1	Law enforcement interaction	Absence of procedures for law enforcement interaction with AVs
RN1	Neutrality regulation	Incompatibility of Network Neutrality directives with applied traffic prioritization techniques

Figure 5 depicts the different issues identified.

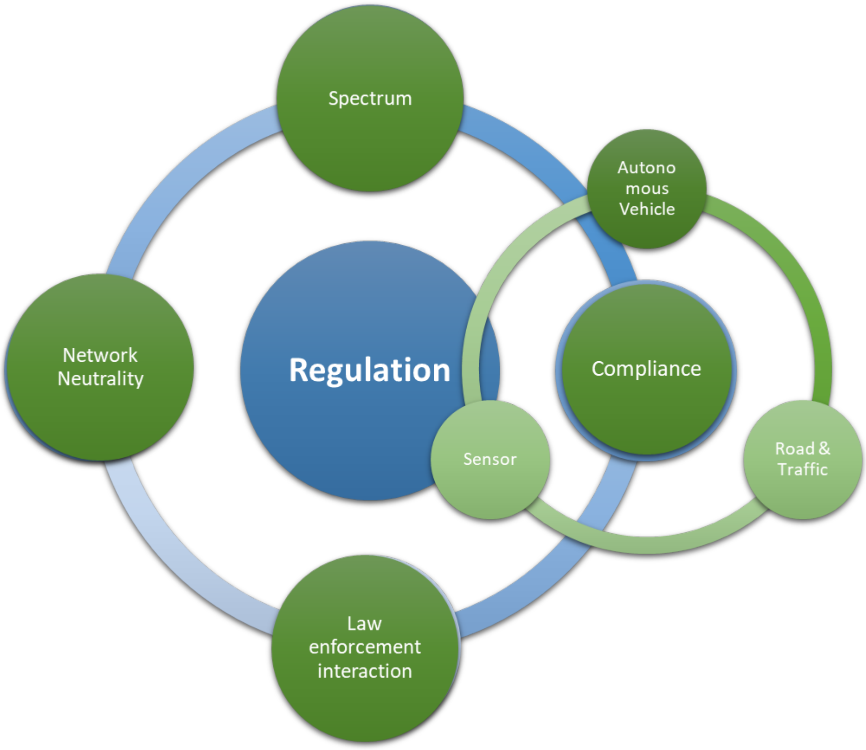

Figure 5 Security & data Privacy issues summary.

3. 5G-MOBIX CROSS-BORDER CORRIDORS

3.1. Spain-Portugal (ES-PT) Cross-Border Corridor

The ES-PT cross-border corridor is in the border of the north of Portugal with Spain. This border is established by the Minho/ Miño river, disposing of several bridges providing the road infrastructure serving trucks, cars and pedestrians. International trade as well as large passenger commuting flows are of great importance and provide ideal conditions for the execution of diversified trials to showcase the advantages offered by the 5G connectivity to CCAM use cases.

3.1.1. Location

Table 6 ES-PT location overview

Trial site class	Corridor
Country/Countries	Spain/Portugal
City/Cities	Vigo / Tui / Valença / Porto

Figure 6 Old bridge over Miño/Minho river in Spain-Portugal Border (where UC3 will take place)

The Spanish-Portuguese corridor connects the cities of Vigo and Porto, with a distance of around 250 Km, and using next roads/highways:

- Spain:

- Urban Roads in the city of Vigo (4 Km).
  - A55 (10 Km).
  - AP9 (5 Km).
- Portugal:
  - A3 (4 Km).
  - N13 (1km).
  - A28 (10 Km) near the Porto Airport and Cruise Passenger Terminal (7 Km).

Current infrastructure in the pilot area is composed by:

- 3G/4G Cellular Communication.
- 1 MEC Node (based on CONCORDA Project)
- ITS-G5
- In-Vehicle Communication Units, developed by CTAG
- Road Side Units, developed by CTAG
- C-ITS Platform to manage the corridor events.

The 5G infrastructure that has been planned for the development of the 5G-MOBIX project is the following:

- In the Spanish side:
  - MEC node with additional capabilities for interconnection with MEC nodes from another operator.
  - Several macro / small cells, initially based on 4G LTE but eventually upgradeable to 5G NR, to reinforce the coverage. The exact number of nodes will depend on the corridor area to be reinforced.
  - A network slicing framework for proper isolation between V2X and eMBB services, based on either SDN/NFV technologies or more traditional means (like e.g. local breakout and QoS differentiation).
  - Several SIM cards properly registered in Telefonica's provisioning systems for access to V2X services
- In the Portuguese side:
  - MEC.
  - 5G base stations (BTS).
  - 5G core.
  - Optical fibre interconnections.
  - IP/MPLS fixed network.
  - Energy power supply.

According to this, the 5G-MOBIX scenario will be the one illustrated in Figure 7.

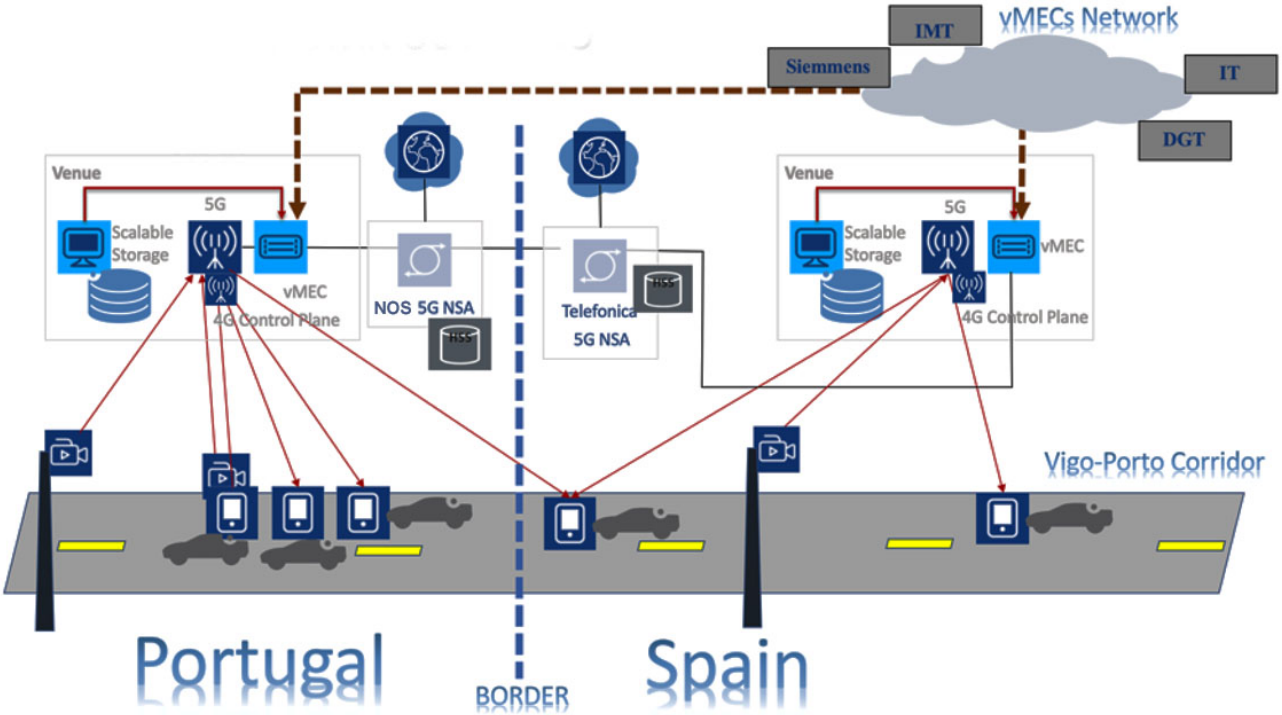

Figure 7 5G-Mobix Scenario

The Spain-Portugal corridor (Figure 8) includes the following locations:

- Spain - Vigo bay.
- Spain - A-55 and AP-9 (near CTAG).
- Border - Old bridge.
- Border - New bridge.
- Portugal - A-28 (segment near the Porto airport and the Cruise Passenger Terminal).
- Portugal - Vigo-Porto highway roads with 5G tests in the new bridge.

Figure 8 Spain-Portugal corridor

3.2. Greece – Turkey (GR-TR) Cross-Border Corridor

The GR-TR cross-border corridor constitutes the south-eastern border of the European Union providing a challenging geo-political environment due to the existence of actual, physical borders, where customs agents perform rigorous border checks. These unique conditions comprise a commensurate testing ground for the operation of CCAM use cases at EU border conditions with heavy traffic and will help determine how the involved stakeholders should adapt to accommodate such functionality. The heterogeneity of traffic going through these borders, i.e. trucks with commercial goods, tourists, as well as the co-existence of multiple differentiated vehicles with pedestrians (security personnel, customs agents, etc.) provide ideal conditions for the execution of diversified trials to showcase the advantages offered by the 5G connectivity to CCAM use cases.

The GR-TR partners will develop the necessary 5G-enabled technology and perform advanced trials for two main CCAM use cases, namely i) truck platooning with "see-what-I-see" functionality and ii) Assisted truck border-crossing & increased driver awareness.

3.2.1. Location

Table 7 GR-TK location overview

Trial site class	Cross-border Corridor
Country/Countries	Greece / Turkey
City/Cities	Kipoi / Ipsala

The GR-TR trials will take place on the most commonly used border crossing between Greece and Turkey in the area of Kipoi (GR) - Ipsala (TR) where the E90 (GR) highway becomes the E84 (TR) highway when crossing into Turkey. Figure 9 depicts the exact location of the GR-TR cross-border trials and the route to be followed by the participating vehicles, covering a stretch of 2.5 kms for testing.

Currently significant efforts are being made on both Greek and Turkish sides to contact all the relevant authorities and ministries in order to guarantee a permit for the actual border crossing of the vehicles. This is a challenging issue since this border crossing is one of the busiest ones in South-East Europe, and security concerns need to be addressed. Irrespective of the trial permit, the trials will have a cross-border character, since coverage from the Greek operator can extend into Turkey to provide handover conditions for the trials. The envisioned direction of trials will be for Ford trucks to start from the Greek side of the borders (communicating over the Cosmote 5G network) and progressively drive towards the Turkish side and handover (one by one) to the Turkcell 5G network.

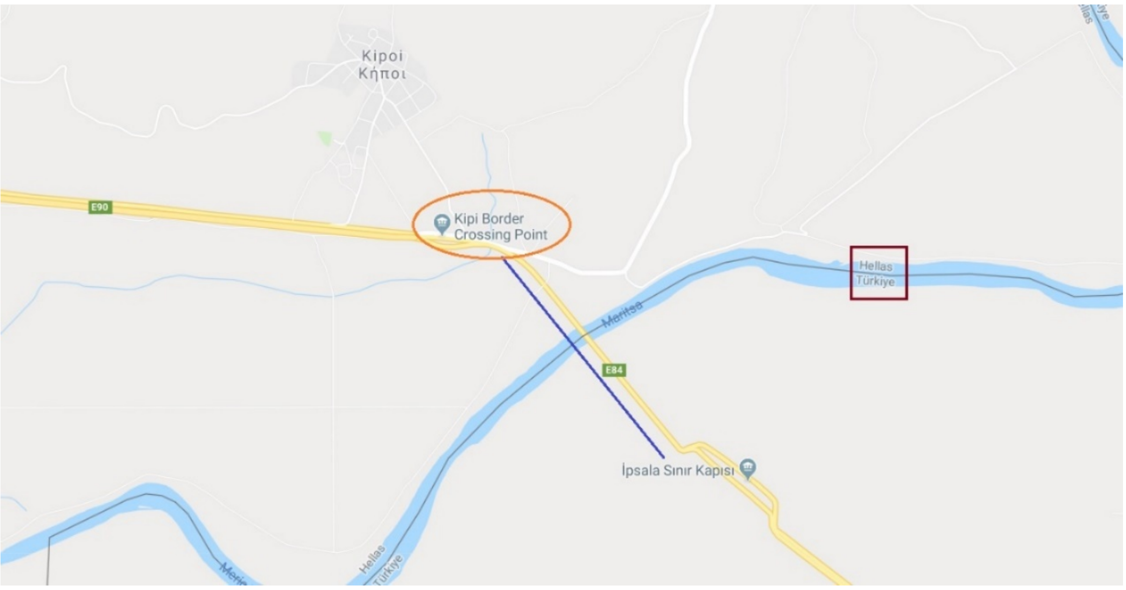

Figure 9 GR-TR border-crossing trial location

Besides the trials at the GR-TR border, initial tests will also be carried out in the Ford Otosan Inonu trial site (see Figure 10) where development of functionality and testing will take place to support the cross-border trials. The knowledge & technology transfer from this trial site will enable the advanced trials taking place at the border, while it also provides an area for long-term development and testing (such long-term activities are prohibitive at the border location).

Figure 10 Ford Otosan trial site to be used for long-term functionality development & testing

4. 5G-MOBIX USE CASE CATEGORIES

4.1. Methodology for use case classification

During the proposal stage, the 5G-MOBIX consortium defined a set of 5G-enabled use cases pivoting around some autonomous driving manoeuvres. Once the project started and during task 2.1 discussions, it was concluded that it was necessary to define some use case categories to classify use cases. This classification would enable the presentation of use cases under a common umbrella and would facilitate the demonstration of their complementarity and alignment.

The first step was to define the criteria for selecting the use case categories. The following requirements were defined:

- The use case categories need to cover all the use cases defined in 5G-MOBIX.
- The use case categories need to be aligned with European Commission's vision of Connected and Automated Driving in 5G Corridors[3].
- The use categories should be well-stablished in the 5G and automotive industries and ideally come from a standards organization.

In order to assess those well-established use categories, the current state of the art on 5G Connected and Automated Driving (CAD) use cases was studied. Firstly, all 5G-PPP Phase 2 projects providing a public deliverable with use cases definition were screened to select the ones including automotive use cases. Unfortunately, no consensus was found between the use case definition and classification as each project used their own terminology and classification criteria. Consequently, no use case classification met the requirements and ambition of 5G-MOBIX.

As a second step on the use case state of the art review, the recommendations and reports issued by 5G and automotive standardisation organization were screened. In this process, the following Technical Specification published by 3GPP was identified:

> *3GPP TS 22.186 V16.1.0 (2018-12). 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Enhancement of 3GPP support for V2X scenarios; Stage 1 (Release 16)*

4.2. Use case categories

This document focuses on 5G radio technology and specifies service requirements to enhance 3GPP support for V2X scenarios in the following areas:

1. Advanced Driving

[3] https://ec.europa.eu/digital-single-market/en/cross-border-corridors-connected-and-automated-mobility-cam

2. Platooning
3. Extended Sensors
4. Remote Driving
5. Vehicle quality of service Support

After a careful study of the 5G-MOBIX use cases, it was concluded that all of them could fall into one of those categories. Furthermore, the categories met all the requirements defined in the first step of the methodology.

In a first iteration, the Technical Coordinator assigned a category to each 5G-MOBIX use case. This classification was then reviewed by the trial site leaders and the Task 2.1 leader. Some minor issues regarding use case classification were discussed in T2.1 weekly conference calls. Finally, a broad agreement was met among task T2.1 participants on the use case classification.

4.3. Taxonomy of 5G-MOBIX use cases

As explained previously, in 5G-MOBIX the use case categories were extracted from a 3GPP Technical Specification. The descriptions given by 3GPP are high-level enough to accommodate very different implementations for each use case category. In the previous version of this deliverable, each of these derivatives proposed by 5G-MOBIX were called use cases. In the present version, the 3GPP **use case category** derivatives are called **user stories**. Therefore, the user stories are defined by 5G-MOBIX under the umbrella of a standard 3GPP classification. In some cases, the user stories have more than one possible event flow. Each of these situations, are called **scenarios**. Not all the user stories need to have more than one scenario, so in case that there is only one, this is implicitly defined in the user story.

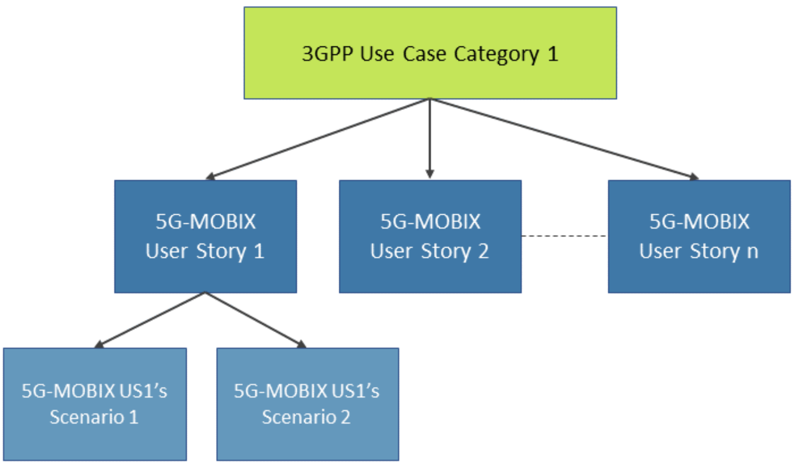

Figure 11 Taxonomy of 5G-MOBIX use cases

Under this taxonomy, one can also say that use case categories can be considered simply as use cases. This is an alternative valid view where there are only 5 big use cases in 5G-MOBIX, distilled from a 3GPP TS, and then we have several user stories under each use case.

In any case, the new taxonomy proposed in the present version of D2.1 aims to have a more integrated consortium working on a coordinate way on each V2X area identified by 3GPP.

The following sections 5 to 9 describe the user stories proposed under each use case category.

5. UC CATEGORY 1: ADVANCED DRIVING

5.1. Description

According to 3GPP TS 22.186 R16, Advanced Driving "enables semi-automated or fully-automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or Road Side Unit (RSU) shares data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or manoeuvres. In addition, each vehicle shares its driving intention with vehicles in proximity. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency".

In 5G-MOBIX there are four user stories described under the category of Advanced Driving:

Table 8 User Stories under Advanced Driving UC category

Advanced Driving User Story	Location
Complex manoeuvres in cross-border settings	Spain-Portugal (ES-PT) cross-border corridor
Infrastructure-assisted advanced driving	French (FR) trial site
Cooperative **Collision** Avoidance	Dutch (NL) trial site
Cloud-assisted advanced driving	Chinese (CN) trial site

In the following section, the main cross-border challenges addressed by these user stories are identified. Then, each of these user stories are described. In the case of user stories not implemented in a cross-border corridor, their uniqueness and their tangible contributions to the corresponding cross-border corridor are described and justified.

More information about these user stories can be found in Annex 3.

5.2. Cross-Border Impact

In the next table, the main technical challenges and issues targeted under this use case category are summarised. The issues targeted by a single trial site are marked in the table with thicker borders.

Table 9 Issues coverage Advanced Driving user stories.

Category	ID	Issue name	ES-PT	FR	NL	CN
Telecommunications	TR1	NSA Roaming Latency				
	TR2	SA Roaming Latency				
	TC1	Continuity Protocol				
	TC2	Performance Continuity				
	TN1	Geo-Networking IP				
	TN3	Geo Networking Overhead				
Application	AC1	V2X Continuity				
	AI1	Data Interoperability				
	AP1	Real-time Multi-tier Processing				
Security & Data Privacy	ST1	Federation Trust				
	ST2	Discovery Trust				
	SP1	Data Privacy				
	SO1	Data Ownership				
Regulation	RC1	Autonomous Vehicle regulation Compliance				
	RC3	Sensor Compliance				
	RN1	Neutrality regulation				

5.3. User stories

5.3.1. User Story #1: Complex manoeuvres in cross-border settings (ES-PT)

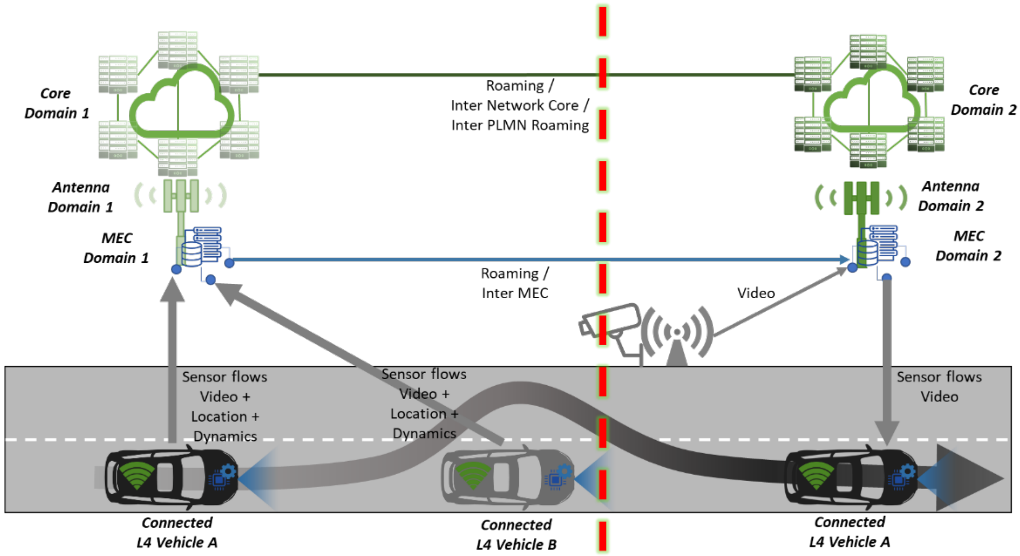

Figure 12 Complex manoeuvres in cross-border settings

This user story consists of three different scenarios where connectivity will support automated manoeuvres in the ES-PT cross-border setting:

- **Scenario 1: Lane merge for automated vehicles:**

This scenario manages the situation where automated vehicles are in a lane merge scenario, analysing the traffic flow of the target lane. In this way, the system can detect existing vehicles including their lane position, acceleration, speed, size, etc. providing an extended perception layer, which is taken into account by the automated vehicle to determine the best merge manoeuvre according to the current situation.

Vehicles in the lane to be merged are connected vehicles that share their vehicle data with the use of a Communication Unit with 5G capabilities and through a MEC Node. Road sensing technologies, such as traffic radars, are also used to detect the presence of vehicles in the target lane and to transmit their position and speed to the automated vehicle.

Automated vehicle uses the Communication Unit as well in order to receive the information sent by surrounded vehicles and the road-side infrastructure, and therefore determine the status of the lane merge and the best way to operate to success in a safe and comfortable lane merge.

- **Scenario 2: Automated Overtaking:**

When an automated vehicle needs to overtake a vehicle that precedes it, additional information provided by communication technologies will drastically improve and complement the information provided by its sensor constellation.

There are many situations where the dimensions of other vehicles can cover the field of view of the autonomous vehicle sensors (for example, a truck can reduce the vision of a camera, a laser or a radar sensor). Moreover, according to the route followed by the vehicle, it can happen that a highway exit or a toll is near to the point where the overtaking takes place, and a queue of vehicles can complicate the scenario reducing free space and therefore producing a less appropriate manoeuvre.

Other complex scenario can appear when there are vehicles behind the automated vehicles that occludes the vision of rear sensors. Considering that we are driving on a two-lane road with a right-hand traffic regulation, this occlusion can produce that the automated vehicle is not able to perceive a vehicle driving fast in the left lane.

The purpose of this use case is to extend the 360º perception layer of the automated vehicle by integrating communication capabilities in the different vehicles of the scenario and additional road sensors (e.g. traffic radars) in the infrastructure. In this way, vehicles will be able to share their positions, speeds, sizes, etc., as well as the road-side infrastructure, helping automated vehicle to understand current situation and thus take the best decision of how to proceed with the automated overtaking.

- **Scenario 3: HD maps:**

This use case focusses in the capability of automated vehicles and road-side infrastructure to detect changes in the road and the HD-Map used for driving, and in sending these changes to the ITS-Centre in order to centralise and broadcast this information to the other approaching vehicles.

Lasers, cameras and traffic radars information can be fused with D-GPS and HD-Maps data, in order to determine changes in the stored information. This information can be measured in terms of length of the event, changes in road description (number of lanes, width of the lanes), dangerousness of the situation, etc.

Finally, obtained data is shared with the ITS-Centre in order to be stored and shared with other vehicles, ensuring the information reaches all the relevant vehicles.

5.3.1.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 10 Issues coverage of Advanced Driving User Story #1 (ES-PT).

Category	ID	Issue name

Telecommunications	TR1	NSA Roaming Latency
	TC1	Continuity Protocol
Application	AC1	V2X Continuity
	AI1	Data Interoperability
Security & Data Privacy	ST1	Federation Trust
	ST2	Discovery Trust
Regulation	RC1	Autonomous Vehicle regulation Compliance

5.3.2. User Story #2: Infrastructure-assisted advanced driving (FR)

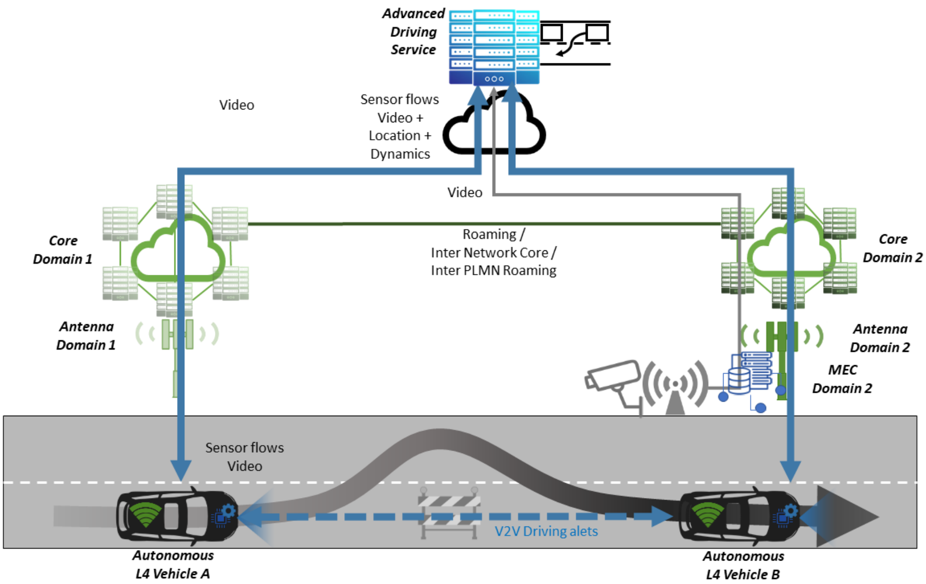

Figure 13 Infrastructure-assisted advanced driving

This user story deals with safe lane change manoeuvre dictated from road operator in presence on a multi-lane highway in presence of separation signs between the different lanes. The most critical factors of lane change manoeuvres comprise the following: a safe distance to the oncoming separation signs when initiating the lane change operation and a safe gap to the connected vehicle behind coming in the same direction, but on a different lane.

Consequently, such a system requires the capability to manage the speed and steering in a coordinated manner, thereby minimizing collision risk with neighbouring vehicles in a hybrid environment (connected, automated, basic vehicles).

In this user story, the MEC will receive two types of data: the first one is provided by the road operator's Traffic Management Centre (TMC) in order to share up to date information about the different types and rules of the toll gates (heavy trucks, CAV, payment methods), while the second data flow will be provided by roadside sensors (such as cameras, lidar) in order to be aware of the presence of separation signs between the different lanes on the roads.

The received raw data will be fused and treated in vicinity of the road entities, i.e. in the MEC, to be quickly processed. After analysing all the input data together with the vehicle related information (location, speed), the MEC will take the lane change decision, calculate the trajectory and will guide the vehicle in order to safely change the lane.

MEC information is given to the automated vehicle in time, so it can start its lane change manoeuvre. The automated vehicle will also inform the connected vehicle coming behind in the same direction about its trajectory change intention to ensure a safe and efficient lane change operation. Involved vehicles will exchange their intended trajectories to coordinate their lateral (steering) and longitudinal controls (acceleration/deceleration) to ensure a smooth manoeuvre. Such a communication should be rapid and reliable enough to guarantee the safety of both vehicles (URLLC service of 5G networks).

5.3.2.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 11 Issues coverage of the Advanced Driving User Story #2 (FR).

Category	ID	Issue name
Telecommunications	TN1	Geo-Networking IP
	TN3	Geo Networking Overhead
Application	AC1	V2X Continuity
	AP1	Real-time Multi-tier Processing
Security & Data Privacy	ST2	Discovery Trust
	SP1	Data Privacy
Regulation	RC1	Autonomous Vehicle regulation Compliance

5.3.2.2. Uniqueness and relevance of the user story implemented at the local site

- FR site focuses on **infrastructure assisted advanced driving** manoeuvre which is unique among TSs

- Infrastructure will use MCS services in order to send trajectory guidance to AV.
- AVs will exchange MCM messages (V2V communication) to negotiate a safe lane change manoeuvre.
- FR tests OBU-based technology selection (5G, PC5, 4G) based on the application type, requirement.
- Currently ES/PT UC is not using roadside perception; FR proposes to extend ES-PT perception by Roadside perception
- Integration of ETSI V2X services/messages by FR site which has already developed and tested these V2X services on other projects (reduce cost of development)
- MEC computing algorithms for extended perception at ES-PT as ES-PT approach for advanced driving decision is vehicle-centric.

5.3.2.3. *Portfolio of transferable assets*

Table 12 Overview of the tangible assets that can be transferred to the CBC from Advanced Driving US#2

Target CBC	ES-PT
List of assets to be transferred to the CBC	• Bringing a connected vehicle to the CBC to interoperate with the other "local" vehicles. • FR Vehicle's OBU will test a different handover scenario using two PLMNs • Integration of ETSI V2X services/messages: ◦ Collective Perception Service/Message from roadside infrastructure (Siemens pedestrian radar) • MEC computing algorithms for extended perception (ongoing discussions) • Geocast messages functionality in MEC, with a different implementation compared to NL site, brought to SP and PT (will be tested in extended sensors category)
Other stakeholders interested on the offering	• Road operators • MNOs • Vehicle provider /OBU provider

5.3.3. User Story #3: Cooperative Collision Avoidance (NL)

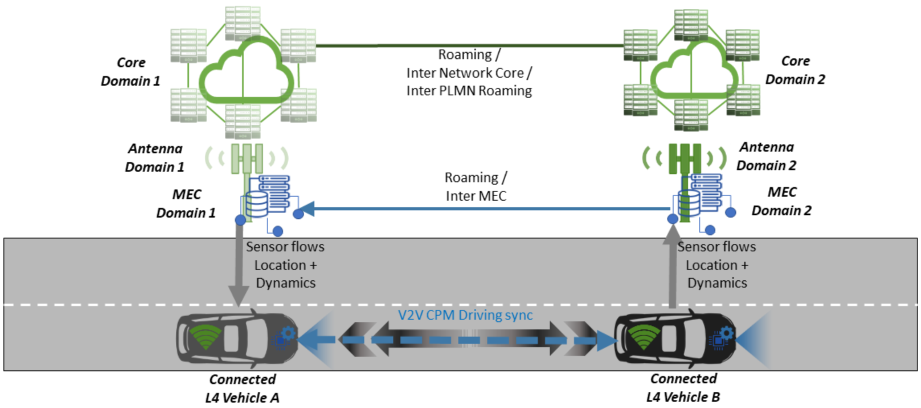

Figure 14 Cooperative Collision Avoidance

This 5G-MOBIX Service will take place at an Intelligent Intersection of the A270 Motorway - N270 Highway between Eindhoven and Helmond (NL). This site has been used for several tests and trials on Automated Driving and/or C-ITC. In 5G-Mobix the current facilities to support CCAM will be upgraded to work on a 5G mobile connectivity platform.

Cooperative Collision Avoidance (CoCA) targets to solve a challenging traffic situation on the motorway/highway environment. The Vehicle A ('ego vehicle', a foreign registered vehicle driving on the Dutch motorway/highway network) will make itself 'visible' and known to other traffic participants and to the infrastructure for Edge Computing through C-ITS messaging via 5G networks, and Cellular V2X (C-V2X) communication i.e. either LTE-based or 5G NR-based V2X. The Vehicle B ('alter vehicle', a Dutch registered vehicle) will submit similar information of its presence, speed and direction of movement to 'ego vehicle' and infrastructure as described above. Hence the 'Edge Cloud' infrastructure facilities can perform calculations and offload from the vehicles to the infrastructure and then return the suggested manoeuvring messages.

At the intersection of A270-N270 roads, the most critical path for cooperative automated driving is the left turn over the direct traffic flow that has a right-of-way for driving in highly automated mode through the intersection. The ego vehicle that is approaching the intersection must be able to clear itself safely across the motorway/highway lanes to join the main traffic flow. When deemed necessary, the ego vehicle need to safely stop autonomously before crossing the motorway/highway and start driving only when its calculated trajectory path is safe and clear for autonomous manoeuvring. For this purpose, the ego vehicle must be able to utilise both its own trajectory and timing data and information from the road side sensors as well as the alter vehicle's precise location, intended direction and speed to avoid collision.

The target in 5G-Mobix is time-critical message exchange between CAVs using 5G technologies. These technologies include:

- C-V2X based on LTE or 5G NR for direct communication between vehicles and 5G networks
- 5G NR enabled base stations (gNB)

- 5G core technologies like Edge Computing ('Edge Cloud ') and Slicing
- Ultra-Reliable Low Latency Communication (uRLLC) to support time-critical communication.

Currently the CAVs are capable to support direct communication between vehicles via ITS-G5 based solutions and/or 4G network-based communication for C-ITS message exchange. The ultimate solution is to use hybrid in-vehicle communication units that can communicate both directly between vehicles and over the network using 5G NR-V2X.

5.3.3.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 13 Issues coverage of the Advanced Driving User Story #3 (NL).

Category	ID	Issue name
Telecommunications	TR2	SA Roaming Latency
	TC2	Performance Continuity
Application	AC1	V2X Continuity
	AI1	Data Interoperability
Regulation	RC3	Sensor Compliance
	RN1	Neutrality regulation

5.3.3.2. Uniqueness and relevance of the user story implemented at the local site

- Focus on precise collision risk detection and calculation.
- Communication approach on Direct V2V using LTE/5G-NR Sidelink or ITS-G5
- Specific approach of NL TS in testing of Manoeuvre Coordination Service (MCS).
- Seamless Handover b/w two independent and different supplier 5G NWs only. NL TS to enhance ES-PT single supplier trials.
- In-vehicle and MEC manoeuvring calculation integration.
- Testing in full highway environment to benefit ES-PT compared to border-crossing site.
- Strong presence and participation of Automotive ITS Actors.

5.3.3.3. Portfolio of transferable assets

Table 14 Overview of the tangible assets that can be transferred to the CBC from Advanced Driving US#3

Target CBC	ES-PT
List of assets to be transferred to the CBC	• CoCA: Application of the Manoeuvre Coordination Service (MCS) • Seamless Hand-over b/w two (2) independent PLMN 5G NWs • Two schemes: In-vehicle based and MEC based application of CoCA • V2N/V2I and Direct V2V • Hybrid scenario with long range (Uu interface) and short range (PC5 interface) • Collision risk detection in CAV application, alternative/backup @ MEC App • Application of MCS in addition to CAM-based manoeuvring – to support other manoeuvring like Overtaking
Other stakeholders interested on the offering	• Automotive industry & suppliers • MNOs & suppliers • Road traffic regulators • Ministries of Traffic, Transport and Communications and relevant government agencies • Highway operators

5.3.4. User Story #4: Cloud-assisted advanced driving (CN)

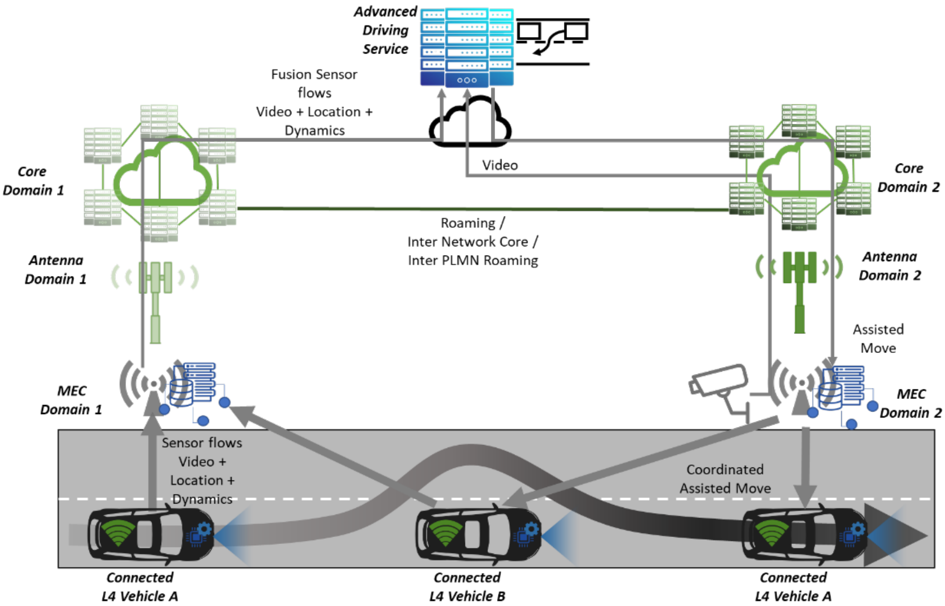

Figure 15 Cloud-assisted advanced driving

In the China site, the roadside unit, remote control centre and cloud server will monitor and control the autonomous vehicles in real time, to realize the various testes of Internet-connected applications of vehicles safely and efficiently. In the high-level abstraction of the user story, Vehicle A and Vehicle B are both running in a straight line along the right lane. Vehicle B is traveling at a constant speed in front of Vehicle A, and both vehicles keep a small distance. In the beginning, the remote-control centre (MEC) issues the overtaking order to vehicle A through the RSU. After receiving the order, Vehicle A sends the overtaking information to Vehicle B through V2V communication and receive the real-time information from Vehicle B via V2V, which includes the position, speed and heading angle of the vehicle. Thus, Vehicle A makes an automatic decision according to the information of Vehicle B.

The decision-making of Vehicle A is detailed as follows: First, it changes to the left lane; then it accelerates to overtake according to the speed of Vehicle B. Finally, it changes lane back to the right lane, and sends its information to Vehicle B. In this way, these two cars complete overtaking operation. In this process, Vehicle A exchanges messages related to CoCA (Coordinated collision avoidance) through the 3GPP V2X communication service, while other vehicles transmit messages through the 3GPP communication service as well, finally they will achieve coordinated manoeuvring.

5.3.4.1. Addressed cross-border issues

This user story is mainly focused on addressing the Data Ownership issue or technical challenge.

Table 15 Issues coverage of the Advanced Driving User Story #4 (CN).

Category	ID	Issue name
Security & Data Privacy	SO1	Data Ownership

5.3.4.2. *Uniqueness and relevance of the user story implemented at the local site*

- **Strong focus on the cloud** to manage the autonomous driving manoeuvres.
- This is the only user story **focused on the data ownership issue**.
- The Chinese trial sites provides a 5G experimental environment that facilitates:
  - Testing different DSRC/ 4G/5G network configurations and handover scenarios (DSRC testing has been completed.)
  - Testing new 5G features (after debugging relevant 5G equipment)

5.3.4.3. *Portfolio of transferable assets*

Table 16 Overview of the tangible assets that can be transferred to the CBC from Advanced Driving US#4

Target CBC	ES-PT
List of assets to be transferred to the CBC	• Edge computing for information fusion and sharing and decision support, based on Multi-MEC handover • Systems preserving data ownership for stored data
Other stakeholders interested on the offering	• Autonomous driving solution providers • Road infrastructure providers

6. UC CATEGORY 2: VEHICLES PLATOONING

6.1. Description

According to 3GPP TS 22.186 R16, Vehicles Platooning "enables the vehicles to dynamically form a group travelling together. All the vehicles in the platoon receive periodic data from the leading vehicle, in order to carry on platoon operations. This information allows the distance between vehicles to become extremely small, i.e., the gap distance translated to time can be very low (sub second). Platooning applications may allow the vehicles following to be autonomously driven".

In 5G-MOBIX there are three user stories described under the category of Vehicles Platooning:

Table 17 User Stories under Vehicles Platooning UC category

Advanced Driving User Story	Location
Platooning with "see what I see" functionality in cross-border settings	Greece - Turkey (GR-TR) cross-border corridor
eRSU-assisted platooning	German (DE) trial site
Cloud-assisted platooning	Chinese (CN) trial site

In the following section, the main cross-border challenges addressed by these user stories are identified. Then, each of these user stories are described. In the case of user stories not implemented in a cross-border corridor, their tangible contributions to the corresponding cross-border corridor are described and justified.

More information about these user stories can be found in Annex 3.

6.2. Cross-Border Impact

In the next table, the main technical challenges and issues targeted under this use case category are summarised. The issues targeted by a single trial site are marked in the table with thicker borders.

Table 18 Issues coverage of Platooning user stories

Category	ID	Issue name	GR-TR	DE	CN
Telecommunications	TR1	NSA Roaming Latency			
	TN2	Hybrid Networking			
	TN4	Inter-MEC Connectivity			
Application	AC1	V2X Continuity			
	AC2	Dynamic QoS Continuity			
	AG1	Accurate Geo-Positioning			
Security & Data Privacy	ST1	Federation Trust			
	ST2	Discovery Trust			
	SP2	Anonym Privacy			
	SO1	Data Ownership			
Regulation	RC2	Road & traffic regulation Compliance			
	RC3	Sensor Compliance			
	RL1	Law enforcement interaction			

6.3. User stories

6.3.1. User Story #1 Platooning with "see what I see" functionality in cross-border settings (GR-TR)

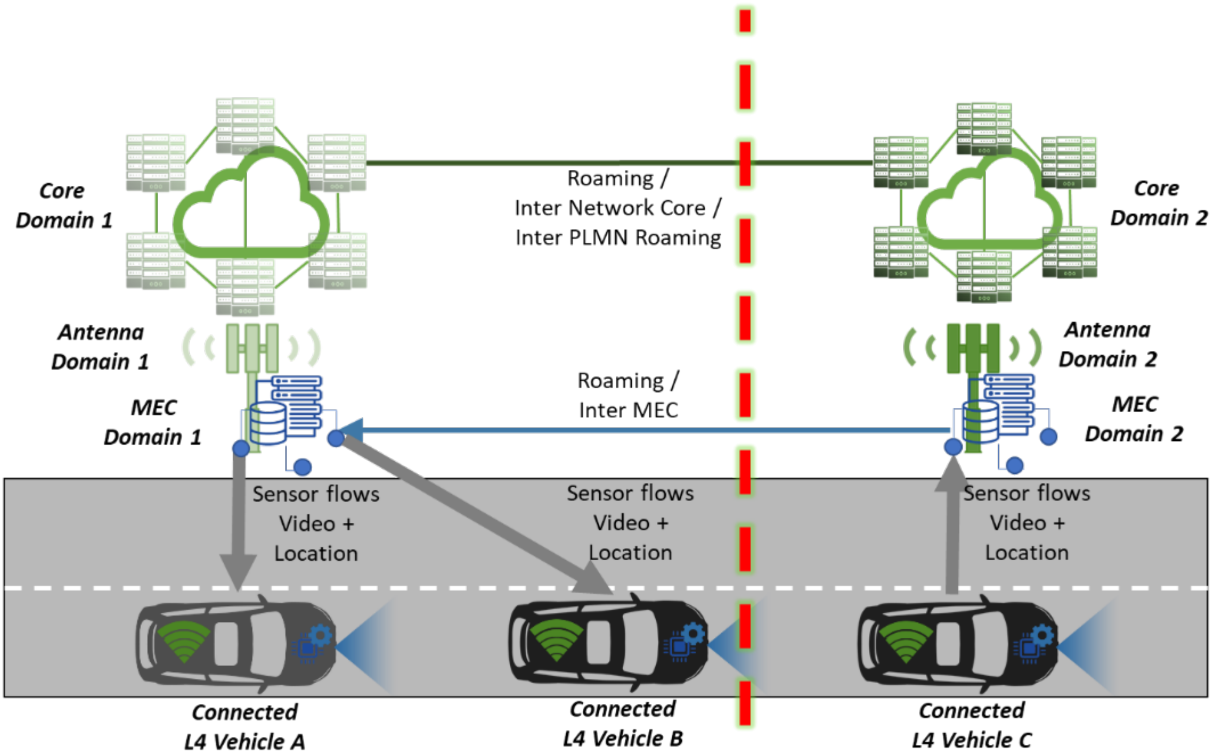

Figure 16 Platooning with "see what I see" functionality in cross-border settings

Observing that there is at least another vehicle on a road, which does not involve intersections and merging with other lanes for a certain time, the two or more vehicles on the move will decide to *form a platoon*. In the platoon, while one of the vehicles take on the role of the leader, which may or may not have an active driver depending on the SAE level of the vehicle itself, the rest of the vehicles may be controlled automatically by the movements of the leading vehicle.

Once the platoon is formed and the "see-what-I-see" application is informed about the presence of the platoon as well as its members with distinct roles to identify the leader and the follower vehicles, a specific ID is assigned to the platoon by the application. Then, the platoon leader will start transmitting a compressed (with H.265/HEVC codec standard) 4K video stream captured by a camera viewing the road in the front of the vehicle, along with the platoon ID, first to the base station, then to the vEPC, which is to transfer the streaming data to the "see-what-I-see" application server. Matching the video with the recipient vehicles that are the follower trucks in the platoon by using the platoon ID, the application server begins sending the video stream to these through the vEPCs and base stations serving them.

All platoon members will be equipped with on board units (OBU) that have the C-V2X communication capability and a connection to the in-cabin displays of the vehicle (such as a dedicated tablet). Additionally, the platoon leader will share road information collected from its sensors such as short and mid-range radars and cameras as well as internal data about its manoeuvres (i.e. emergency brake, speed up-down etc.) over the PC5 interface with the follower vehicles.

When the platoon arrives to the customs site between Turkey and Greece borders, the platoon is dissolved for further controls at the borders. At this stage, the objective is to allow the truck drivers handle required documentation while the trucks move autonomously at the customs site to visit each of the checkpoints as dictated by the customs agency. For the autonomous crossing of the trucks between the borders, the customs site will be equipped with several sensors and road side units (RSUs) in addition to the 5G network infrastructure. All sensory information from the vehicles and the surrounding will be gathered at the network edge to be processed by an application, which will determine the safest paths for each of the vehicles at the customs site, dynamically shaping their whole trajectory.

After the "truck routing in customs site" is over with no obstacles detected for passage through the border and the drivers have completed their paperwork, they will return to their vehicles. Upon exiting the customs site, the platooning operation and thus the "see-what-I-see" functionality will be initiated again. The final destination of the platoon will be Greece.

While the platoon goes from Turkey to Greece, it is anticipated that at some point, which depends specifically on the radio signal propagation characteristics of the 5G networks, the vehicles in the platoon will roam from the Turkish (Turkcell) operator to the Greek (Cosmote) operator, where an uninterrupted video stream will flow from the leader truck to the follower trucks throughout the roaming procedure.

6.3.1.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 19 Issues coverage of Platooning User Story #1 (GR-TR).

Category	ID	Issue name
Telecommunications	TR1	NSA Roaming Latency
	TN4	Inter-MEC Connectivity
Application	AC1	V2X Continuity
	AG1	Accurate Geo-Positioning
Security & Data Privacy	ST1	Federation Trust
	SP2	Anonym Privacy

Regulation	RL1	Law enforcement interaction

6.3.2. User Story #2 eRSU-assisted platooning (DE)

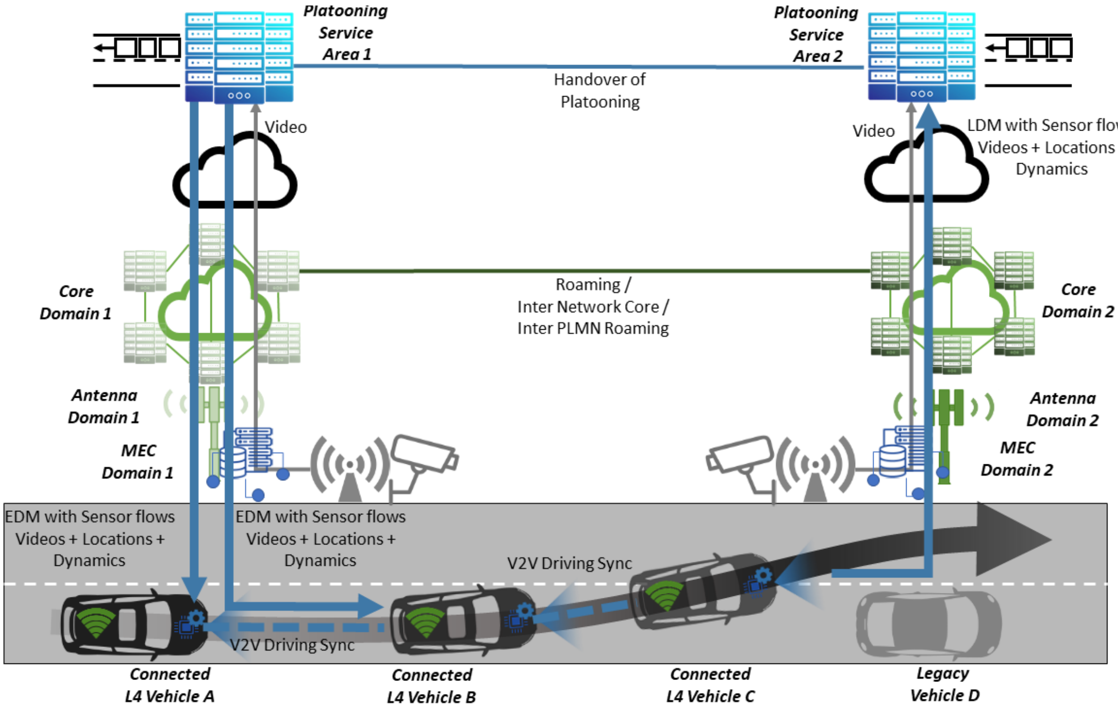

Figure 17 eRSU-assisted platooning

In this use case, a platoon of 3 AVs is operating along a road. The platoon approaches a truck. At 500m to a junction, the truck signals its intention to take the right turn and slows down.

A local EDM instance deployed on an eRSU located at the junction, detects the truck's changing velocity and trajectory through learned pattern recognition from local sensor data. It updates the global map and notifies the centralized traffic management & planning applications through eRSU's upstream interfaces.

The platoon leader detects a potential collision as it approaches the truck and request the EDM from the eRSU. The route planning service in the eRSU detects a possible overtaking manoeuvre due to low traffic ahead and possibly adapted green light phase for extended free flow based on information from traffic management system.

Based on the information provided by the eRSU and its services, the platoon leader initiates an overtaking manoeuvre by communicating context data (location, speed, LDM) to the eRSU. Using the EDM, the route planning service in the eRSU formulates the overtaking manoeuvre and communicates the overtaking plan to the platoon leader.

During the overtaking manoeuvre, the platoon enters the coverage of an eRSU of another provider. This results in eRSU handover with upstream gateway relocation from current MNO's eNB/gNB to new MNO's. In effect, the ITS instances and context on source eRSU must be handed over to the new eRSU. At mobile network level, this handover is carried out with handover protocol between the MNOs' core networks. At application level, resource and service allocation are orchestrated by the centralized ITS service entities, which are made aware of mobile network and MEC provisioning.

6.3.2.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 20 Issues coverage of Platooning User Story #2 (DE)

Category	ID	Issue name
Telecommunications	TR1	NSA Roaming Latency
	TN2	Hybrid Networking
Application	AC1	V2X Continuity
	AC2	Dynamic QoS Continuity
Security & Data Privacy	ST1	Federation Trust
	ST2	Discovery Trust
Regulation	RC2	Road & traffic regulation Compliance
	RC3	Sensor Compliance

6.3.2.2. Uniqueness and relevance of the user story implemented at the local site

- This is the only user story of the category with a **V2V platooning message pipeline** and an **intensive MEC processing** for **EDM generation** including an **RSU-driven** approach.
- User story at GR-TR delivers 4K video streams from platoon leader to members over 5G network and streaming service/server. Going beyond, DE requires a different type of solutions:
  - Pipelining vehicle data among vehicles and mainly rely on C-V2X and RSUs infrastructure for data communication and processing
  - Demanding and scalable processing performed at the MEC for EDM ROI filtering
- Roaming scenario of the GR-TR requires network handover (multi-PLMN) as streaming service is hosted on the cloud. However, applications are deployed at the eRSUs in DE:
  - Roaming scenario requires replication of CCAM services (states) from RSU to RSU.
  - Management and orchestration component for RSU MEC resources & network

- The user story implemented at China TS is focused on addressing a different cross-border issue: data ownership from the different data flows exchanged by the actors. In addition, the present user story has the following differences:
  - Adaptation of LDM/EDM formats, encodings and resolutions.
  - Availability of RSUs. Requires more intensive data communications.
  - Demanding and scalable processing performed at the MEC for data fusion and EDM ROI filtering.
  - Multiple network slicing approaches. Here the focus is on multi-domain slicing infrastructure orchestration.

6.3.2.3. Portfolio of transferable assets

Table 21 Overview of the tangible assets that can be transferred to the CBC from Platooning US#2

Target CBC	GR-TR

List of assets to be transferred to the CBC	• Portable Vehicle Sensor Platforms (3 different vehicle setups: Valeo, Vicomtech and TUB)
	• Portable eRSU platform with MEC
	• V2V platooning messages pipeline: instant time-based bus
	• LDM&EDM Software
	  • MEC/Infrastructure assisted Computer vision
	    ▪ LDM constructing HD-maps to be shared among AVs
	    ▪ Interface for EDM data querying. A ROI is extracted according to the geolocalisation and direction of the vehicle's request.

Other stakeholders interested on the offering	• Berlin City has strong interests in the DE AD testbed and plans to extend such infrastructure to multiple sites • New business model for road infrastructure provider, who may be interested in investing in RSU and near edge infrastructure

6.3.3. User Story #3 Cloud-assisted platooning (CN)

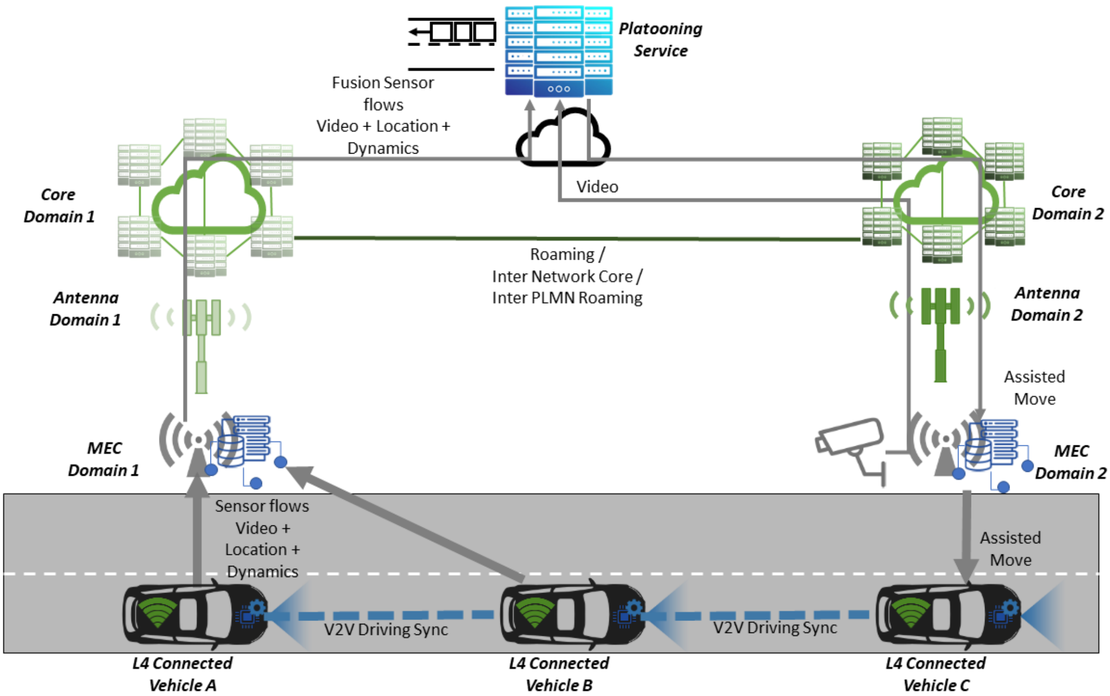

Figure 18 Cloud-assisted platooning

The autonomous driving vehicle fleet communicates with each other through LTE-V at the start. Among them, the leading vehicle includes the platoon control unit (PCU), which coordinates the vehicles in the fleet to ensure a certain safe distance and to drive in a platoon. The leading vehicle communicates with the control centre deployed in a cloud server through V2N to obtain the test scheme and the global path planning. Then it provides the basic planning for the rear vehicle through V2V communication (including chasing, continuous running, acceleration, deceleration, obstacle avoidance, overall acceleration, and deceleration, etc.). The following vehicle also has a certain perception and planning decision-making ability. Besides, LTE-V communication can be replaced by DSRC technology, and comparison between these two methods will be implemented.

6.3.3.1. Addressed cross-border issues

This user story is mainly focused on addressing the data ownership issue or technical challenge.

Table 22 Issues coverage of the Platooning User Story #3 (CN).

Category	ID	Issue name
Security & Data Privacy	SO1	Data Ownership

6.3.3.2. *Uniqueness and relevance of the user story implemented at the local site*

- **Strong focus on the cloud** for managing the platooning manoeuvres.
- Presence of two MNOs (China UNICOM, China MOBILE) with two vendors (ZTE, HUAWEI).
- Only platooning user story that **addresses** the **data ownership issue**.
- In addition to regular automated car with 5G modules, the Chinese trial site has also some remote-controlled miniature vehicles which are much more flexible than the trucks used at GR-TR.

6.3.3.3. *Portfolio of transferable assets*

Table 23 Overview of US#3 contributions to CBC

Target CBC	GR-TR
List of assets to be transferred to the CBC	• 5G-capable test vehicles for testing platooning. • 5G OBU. • Specifications for assuring data ownership for a platooning scenario.
Other stakeholders interested on the offering	• 5G equipment Supplier: HUAWEI, ZTE • Self-driving technology company: SDIA, CNHTC • MNOs: China UNICOM, China MOBILE • Road infrastructure contractor: QLTD • Traffic management department: QLTD

7. UC CATEGORY 3: EXTENDED SENSORS

7.1. Description

According to 3GPP TS 22.186 R16, Extended Sensors "enable the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation".

In 5G-MOBIX there are four user stories described under the category of Extended Sensors:

Table 24 User Stories under Vehicles Platooning UC category

Advanced Driving User Story	Location
Extended sensors for assisted **border-crossing**	Greece - Turkey (GR-TR) cross-border corridor
EDM-enabled extended sensors with surround view generation	German (DE) trial site
Extended sensors with **redundant edge processing**	Finnish (FI) trial site
Extended sensors with **CPM** messages	Dutch (NL) trial site

In the following section, the main cross-border challenges addressed by these user stories are identified. Then, each of these user stories are described. In the case of user stories not implemented in a cross-border corridor, their tangible contributions to the corresponding cross-border corridor are described and justified.

More information about these user stories can be found in Annex 3.

7.2. Cross-Border Impact

In the next table, the main technical challenges and issues targeted under this use case category are summarised. The issues targeted by a single trial site are marked in the table with thicker borders.

Table 25 Issues coverage of Extended Sensors user stories

Category	ID	Issue name	GR-TR	DE	FI	NL
Telecommunications	TR2	SA Roaming Latency				
	TH2	Low coverage Handover				
	TC1	Continuity Protocol				
	TC2	Performance Continuity				
	TS1	Service & device isolation				
	TS2	Edge Service lifecycle				
Application	AC1	V2X Continuity				
	AI1	Data Interoperability				
	AI2	Stack Interoperability				
	AG2	Geo-driven Discovery				
	AP1	Real-time Multi-tier Processing				
	AP2	On-demand Processing				
Security & Data Privacy	ST2	Discovery Trust				
	SP1	Data Privacy				
	SP2	Anonym Privacy				
Regulation	RC1	Autonomous Vehicle regulation Compliance				
	RC2	Road & traffic regulation Compliance				
	RC3	Sensor Compliance				
	RG1	Geo-dependant spectrum				
	RN1	Neutrality regulation				

7.3. User stories

7.3.1. User Story #1 Extended sensors for assisted border-crossing (GR-TR)

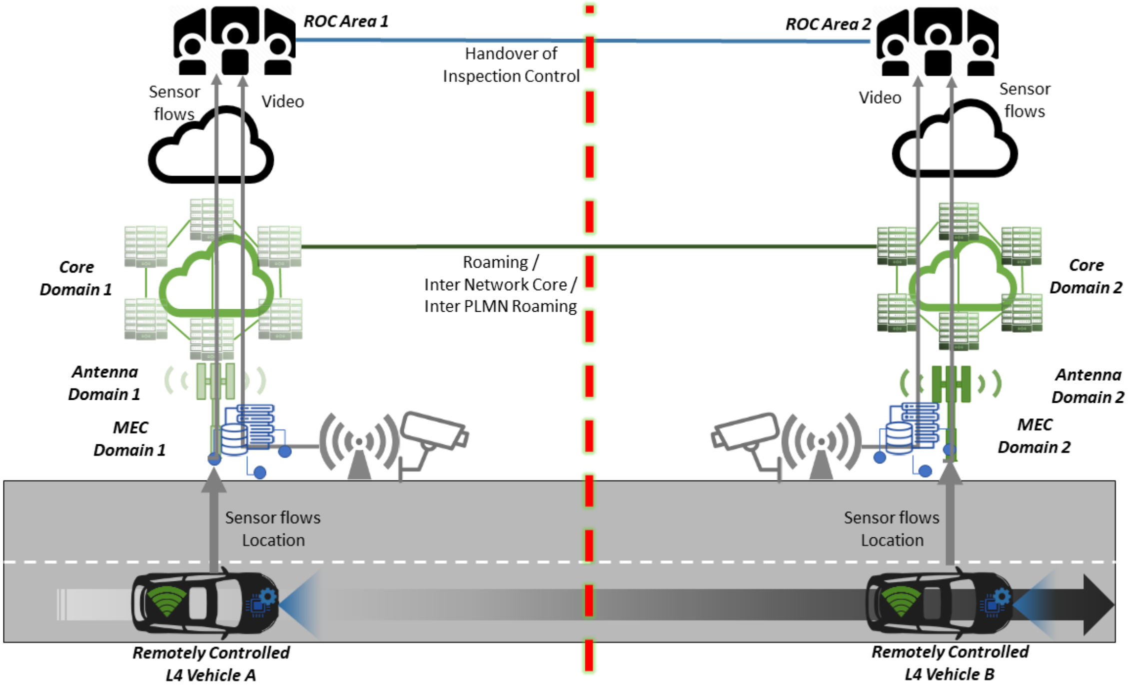

Figure 19 Extended sensors for assisted border-crossing

By utilizing the detailed data provided by the CCAM enabled truck's sensors (Lidar, radar, GPS, etc.) as well as the data from surrounding heterogeneous information sources such as traffic cameras, road side sensors, smart phones, wearables and more, increased intelligence can be created based on a cooperative awareness of the borders' environment. The transmission of these data over reliable, ultra-fast and ultra-low latency 5G network connection combined with modern AI and predictive analytics techniques (at the edge) allows for the creation of a virtual environment of the driver enabling various added-value functionalities. As part of this use case the functionalities that will be showcased at the Greek / Turkish borders are:

- Border inspection preparation based on predictive CCAM truck routing
- Secure CCAM truck border crossing with increased inspection confidence
- Increased border cooperative environment awareness for incoming vehicles
- Increased border personnel safety

The above functionalities will showcase a significant minimization of inspection times at all European "hard" borders through the collaboration feasible of different 5G network operators which could even offer "zero touch" inspection (no human intervention needed) in optimal cases. The same solution offers increased cooperative awareness for passing vehicles at the chaotic border-crossing environment and taking advantage of the CCAM functionalities of vehicles, such as automated braking, to prevent accidents involving border personnel (customs agents, police officers).

This intelligent border control functionality may be realized through the following trial set-up. Data originating from the truck sensors in areas around the borders are transmitted over 5G networks and analysed in a cloud-based AI platform after fusion. Once a trajectory towards the border crossing is predicted, special measures may be taken to facilitate further exchange of information and immediate response to predicted events (e.g. the assisted driving application may be downloaded from the Cloud to the edge server to minimize latency, a slice may be provisioned towards a cloud server on the neighbouring county's PLMN, etc.). An exchange of available information is commencing towards the border authorities via 5G network (mMTC type of communication from the truck OBU itself or even from the cargo which may be equipped with relevant sensors / transmitters (e.g. NB-IoT)) which will facilitate the border inspection and prepare the customs agents for the appropriate checks. All relevant information is transmitted to the edge / MEC servers available at the trial site where they are processed by the downloaded AI/ML platform instantiating this functionality.

Additional information can be exchanged over the 5G networks of the neighbouring countries facilitating the acquisition of relevant information about the specific truck (e.g. driver's information, travel history, cargo inventory, etc.) which could speed-up the control process. Extra security and control measures can be deployed which are controlled and managed through 5G networks such as drones, street cameras, thermal or x-ray cameras, etc. and which can feed large amounts of data (eMBB functionality) in a very short amount of time. In the case that all the acquired data from on-board as well as surrounding sensors / devices agree with the information that is fetched by national archives regarding this truck (and potentially its driver) and provided material (video, thermal imaging, x-ray imaging) clears the truck of any suspicion, then a case of "zero touch" inspection may be realized in which case the truck may be allowed to cross-the border without any manual inspection performed on it.

Additionally, the data originating from other vehicles, road side infrastructure, smart phones and wearables may also be fused and analysed at the edge generating a "live" cooperative update of the surrounding environment which can be fed on to the vehicles navigation system, thus increasing the environmental awareness of the vehicle (covering blind spots, pedestrian locations and trajectories, assigned inspection lane by the authorities, etc.) and actively contributing to the safety of the border ground personnel (i.e. automated trajectory alignment or braking upon detection of a potential incident).

In all cases, the same services continue being provided as the truck passes the border from the neighbouring country's network, based on exchanged information in such inter-PLMN scenarios. Service continuity during the inter-PLMN HO is of utmost importance in such cases, and the existence of such intelligence deployed at the edge close to the border greatly facilitates continuous service by identifying imminent HO's and helping the MNOs prepare for it based on the available information. This could lead to the provisioning of a roaming slice before the HO even takes place.

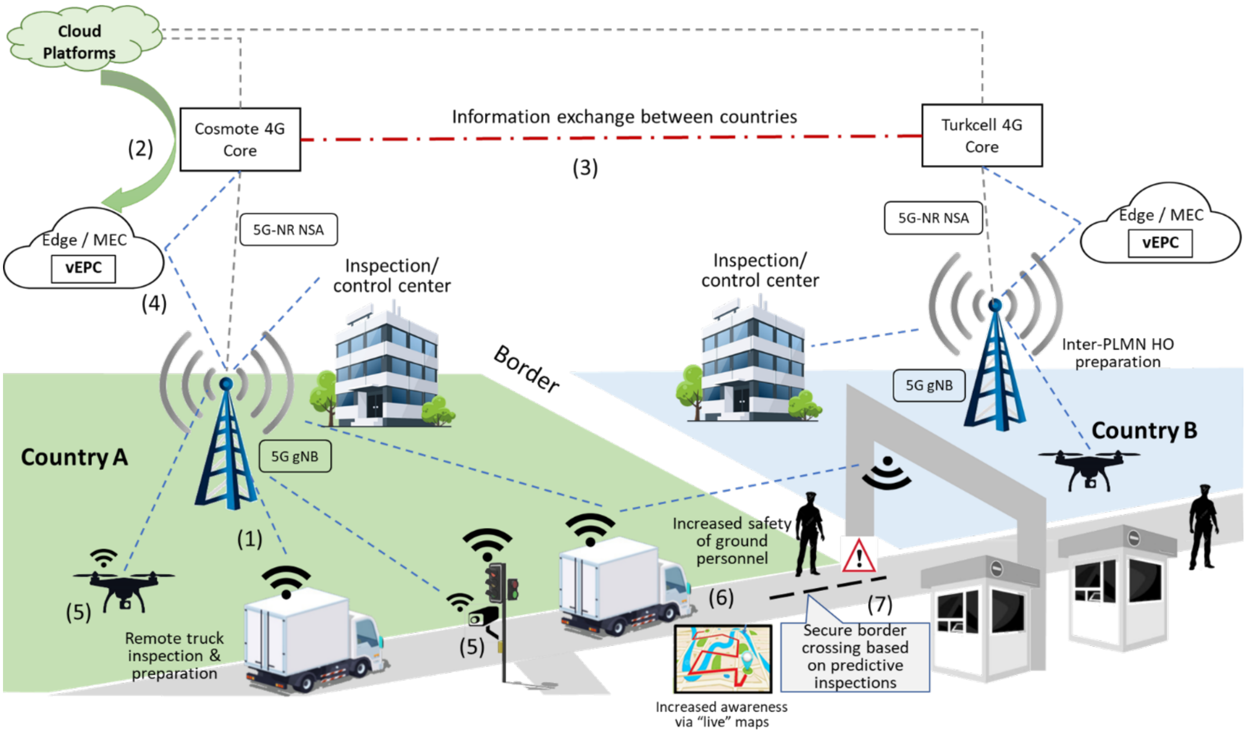

Figure 20 Detailed depiction of "Extended sensors for assisted border-crossing" architecture

To implement this use case a laptop onboard the truck will be acting as the UE/gateway that will connect truck and/or cargo devices/systems (e.g. additional sensors deployed in the cargo hold of the truck) to the rest of the system via 5G connectivity (and 4G / NB-IoT during testing & development). These additional sensors are crucial in this case since they have the capability of raising alarms by cross-checking their data with nominal values. For instance, a thermal camera (or even CO_2 sensor) installed in the cargo hold of the truck may provide indications of a human presence in the cargo hold (smuggling / human trafficking attempt) which will enable alerted reaction by the border officers upon the arrival of the truck at the border.

Additional measures may take place in case contradicting information is gathered regarding a truck, in which case drones equipped with cameras for live feed may be deployed or thermal or x-ray imaging may be requested to rule out the possibility of smuggling goods and people. The AI based inspection functionality residing in the edge platform will fuse all available information from these heterogeneous sources (potentially originating from different 5G networks in the case of a cross-border scenario) and will locate potential inconsistencies, assigning a certain risk factor to each truck which will affect the degree (and thoroughness) to which border agents will perform a manual inspection. For the realization of this trial a single autonomous truck is needed equipped with additional sensors.

7.3.1.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 26 Issues coverage of the Extended Sensors User Story #1 (GR-TR).

Category	ID	Issue name
Telecommunications	TH2	Low coverage Handover
	TC1	Continuity Protocol
Application	AP1	Real-time Multi-tier Processing
Security & Data Privacy	SP2	Anonym Privacy
Regulation	RC1	Autonomous Vehicle regulation Compliance
Regulation	RG1	Geo-dependant spectrum

7.3.2. User Story #2 EDM-enabled extended sensors with surround view generation (DE)

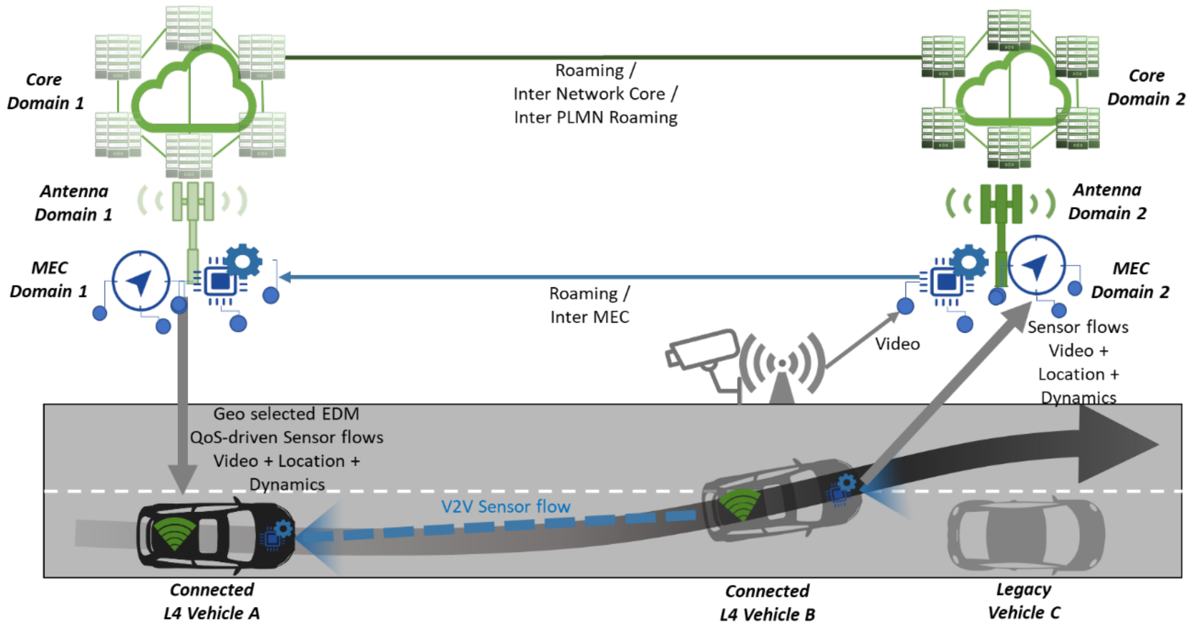

Figure 21 Extended sensors with surround view generation

The objective of this user story is to share LDM data and raw sensor data for real-time prediction and planning tasks made possible by 5G technology. More precisely, the use case deals with a situation when the perception obtained by the on-board sensors is not enough and needs to be enhanced by sensor data from other traffic participants.

The user story contains several connected vehicles equipped with sensors as well as roadside infrastructure comprising sensors and edge computing infrastructure (eRSU). The vehicles and the eRSU using their respective sensor data build their individual situational awareness, identifying objects, lane markings or the road condition to support their prediction and planning functions. However, each individual vehicle's sensors as well as roadside sensors are limited in the perception in different ways. The sensors view could be obstructed by objects, limited by weather conditions, or not covering a specific area. To mitigate the lack of environment information, vehicles share extracts ROIs (regions of interest) from their LDMs and/or sensor raw data and the eRSU shares its Edged Dynamic Map (EDM).

In the proposed setup, the eRSU assisted map update is valid within the coverage area of the eRSU. Cars not within the coverage area are relying on updates of their respective eRSU and their neighbouring vehicles. To assist cars moving from one coverage area to another, the future eRSU's EDM will be provided. Neighbouring eRSUs exchange their EDMs to provide the vehicles with map information when approaching a new coverage area.

The storyline of the use case goes like this. There are two connected autonomous cars driving on the same lane. The two cars are sending relevant LDM data to the corresponding eRSU where the EDM is updated. Suddenly, there is an unexpected event that makes the first car brake and start a lane changing manoeuvre. The event can be for instance a vehicle that stops and blocks the lane. This sudden action is propagated to the rest of the cars that perceive that something is happening. The two connected and automated cars request the EDM to the eRSU under their coverage and they fuse it with their LDM to analyse the situation. They determine that a lane changing manoeuvre is necessary as the lane is blocked some meters ahead. Using the collected information, they start planning and executing the manoeuvre. The EDM contains only processed lightweight data of traffic participants (mainly position, heading, size and speed) that is sufficient for rapid risk estimation and decision making but it is not enough to create a 360º surround view. To favour a quick decision the eRSU provide to each vehicle a filtered EDM with the relevant items for the ROI of the vehicle, filtering any irrelevant data for the vehicle's path. The rear vehicle has its field of view severely restricted and determines that a surround view generation would help keeping the driver in the loop and decreasing the risk of the lane changing manoeuvre. The leading vehicle has better visibility and the do not require a surround view. Consulting the EDM, the rear vehicle selects to which vehicles it needs to request raw sensor data to enhance its field of view. The vehicle generates a 360º surround view by fusing onboard sensors (cameras and Lidar) and data (video and Lidar's 3D cloud) coming from the selected traffic participants. This is done by direct Vehicle to Vehicle (V2V) communication. According to the processing capacity of data source and destination and the network performance between V2V communication participants, the data origin vehicle generates data streams with an appropriate resolution and bitrate. Furthermore, the eRSU provides tokens to be used to perform secure data transfer between the vehicles.

7.3.2.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 27 Issues coverage of Extended Sensors User Story #2 (DE)

Category	ID	Issue name
Telecommunications	TS1	Service & device isolation
	TS2	Edge Service lifecycle
Application	AI1	Data Interoperability
	AG2	Geo-driven Discovery
Security & Data Privacy	SP1	Data Privacy
Regulation	RC2	Road & traffic regulation Compliance

7.3.2.2. Uniqueness and relevance of the user story implemented at the local site

- The German user story is the only one generating an **EDM** and a **surround view**, which can also be useful in GR-TR to increase the awareness.
- The German user story is the only one with a **demanding and scalable processing performed at the MEC for data fusion and EDM ROI filtering,** including the challenge of MEC handover dealing with EDM overlaps. The algorithms running in the MEC could be moved to the cloud if necessary due to GR-TR constrains.
- Different approach than the GR-TR user story:
  - "Zero touch inspection" application at GR-TR vs driving manoeuvres at DE.
  - Forced data sharing (hard border and customs RSU infrastructures) vs on-demand sensor subscription (optional AD support).
- Other distinctive features of the DE user story:
  - Distributed processing within RSU infrastructure.
  - Rely on RSU infrastructure using C-V2X instead of cloud-based service and 5GC network.
  - DE requires adaptation of LDM/EDM formats, encodings and resolutions since LDMs are shared beyond vehicle's onboard systems.
  - Encryption of data flows.
  - Negotiation of data throughput to be sent to another vehicle.
  - Roaming scenario requires migration of CCAM services among RSU infrastructure.
  - Multiple network slicing approaches are planned. Focus on multi-domain slicing infrastructure orchestration.

7.3.2.3. *Portfolio of transferable assets*

Table 28 Overview of the tangible assets that can be transferred to the CBC from Extended Sensors US#2

Target CBC	ES-PT

List of assets to be transferred to the CBC	• On board:
	  • SW: Generation of 360° surround view. Video data received from other vehicles is processed to generate a 360º view. The camera images streamed from remote vehicles need to be projected in the ego-vehicle frame and then stitched together to create the 360º image.
	  • SW: Local Dynamic Map generation (aggregate dynamic elements and locate them relative to the map)
	  • SW: Module for EDM queries. A module that queries the EDM and receives a region of interest of the EDM according to the position of the vehicle requesting it, thus, it receives the information of the surrounding of the vehicle. The information obtained from the EDM can be used for several purposes: LDM enhancement, vehicle/pedestrian discovery, or to predict the scene evolution (for instance for an electronic horizon provider).
	• MEC:
	  • SW: MEC/Infrastructure assisted Computer vision
	    ▪ Construction of Edge Dynamic Map (EDM) with the information obtained from surrounding vehicles and roadside sensors.
	    ▪ Interface for EDM data querying. A region of interest (ROI) is extracted according to the geolocalisation of the interested vehicle.
	• Portable eRSU platform with MEC
	• 2 test vehicles (Valeo's and Vicomtch's)

Other stakeholders interested on the offering	• Berlin City has strong interests in the DE AD testbed and plans to extend such infrastructure to multiple sites • New business model for road infrastructure provider, who may be interested in investing in RSU and near edge infrastructure.

7.3.3. User Story #3 Extended sensors with redundant Edge processing (FI)

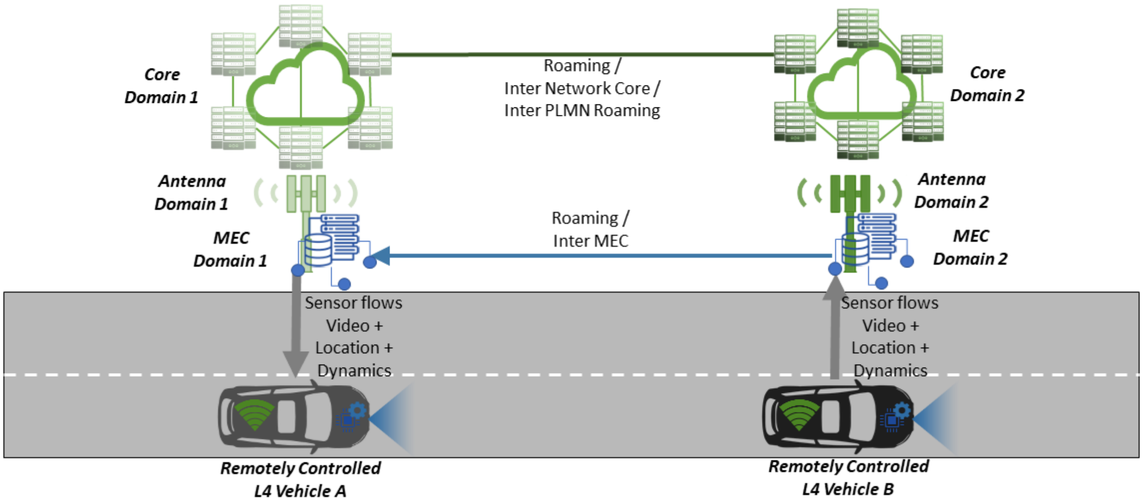

Figure 22 Extended sensors with redundant Edge processing

In this use case, we take video-based cooperative perception for automated vehicles and evaluate the reliability and performance of networking and edge computing services in x-border scenarios. We will evaluate the functionalities and performance (e.g. processing delay, migration overhead) of an automated vehicle using edge computing for cooperative perception, including auto discovery of edge nodes, adaptive task allocation, and seamless service migration. When a V2N connection is established, the automated vehicle receives the network address of an edge node connected with the same 5G base station. Since an automated vehicle is connected simultaneously to two networks, it is connected by default to two edge nodes at the same time. Data generated by the automated vehicle is forwarded to both edge nodes for processing. When the automated vehicle receives the processing results from one edge node already, it can cancel the task on the other edge node. When the automated vehicle is connected to a different network, services will also migrate to an edge node connected to the newly connected base station.

7.3.3.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 29 Issues coverage of the Extended Sensors User Story #3 (FI)

Category	ID	Issue name
Telecommunications	TC2	Performance Continuity
	TS2	Edge Service lifecycle
Application	AI2	Stack Interoperability

	AP2	On-demand Processing
Security & Data Privacy	ST2	Discovery Trust
	SP2	Anonym Privacy
Regulation	RC2	Road & traffic regulation Compliance
	RC3	Sensor Compliance

7.3.3.2. Uniqueness and relevance of the user story implemented at the local site

- Only user story of this category doing **redundant edge processing**.
- Only User Story of this category addressing APIs Interoperability, On-demand Processing and Discovery Trust cross-border issues.
- FI trial site is a 5G experimental environment, that facilitates:
  - Impact analysis of critical network events, e.g. inducing network failure.
  - Testing different 4G/5G network configurations and handover scenarios.
  - Evaluating new 5G features (e.g. deployment modes other than NSA Mode 3).

7.3.3.3. Portfolio of transferable assets

Table 30 Overview of the tangible assets that can be transferred to the CBC from Extended Sensors US#3

Target CBC	GR-TR
List of assets to be transferred to the CBC	• Computer vision features. Video collected from moving vehicles or road side infrastructure will be forwarded to edge computing nodes for processing. The edge computing nodes may be co-located with base stations, or somewhere with short network latency. 1. Real-time object recognition which detects and locating moving vehicles, pedestrian and obstacles such as fences. 2. Vision-based mapping and localization which builds and updates 3D point clouds from crowdsourced video/images and locate objects (including vehicles, traffic signs, and construction sites) in 3D point clouds. The map information will be cached at edge computing nodes and shared with vehicles entering the coverage areas of the edge computing nodes. • The LEVIS (Live strEaming VehIcle System) platform from AALTO is used to obtain HD video streams (with location tags) from vehicle(s) and relaying it authorized subscribers of the stream. The LEVIS-Client

	application is deployed in the vehicle on a single-board computer (e.g. Raspberry-Pi) to gain access to the vehicle's camera(s). It provides users with services including Live Streaming, Local Recording and Uploading Recorded Streams.The LEVIS server-side platform offers the streams to subscribers with services including Live Streaming, Local Recording and Uploading Recorded Streams. The LEVIS-Server (web platform) offers a secure platform that enables only authenticated subscribers to access the different streams for watching and enables streams' owners to manage their streams. In the case of remote driving use case, the subscribers would include the remote operator(s). The record and playback enable the remote operator to have the possibility to view video footage taken from the vehicle prior to a remote driving request. For instance, video footage taken 5-10s or 50m before the remote driving request was triggered would allow the remote operator to have further understanding of the triggering events.
Other stakeholders interested on the offering	• TRAFICOM (national telecom and transport authority): FI user stories validate some CCAM scenarios discussed at international regulatory level and around other two corridors in Finland: Aurora (FI-NO) and Nordic Way 2 (FI-SE-NO-DK) • Also: autonomous driving solution providers, telecom operators and edge computing service providers

7.3.4. User Story #4 Extended sensors with CPM messages (NL)

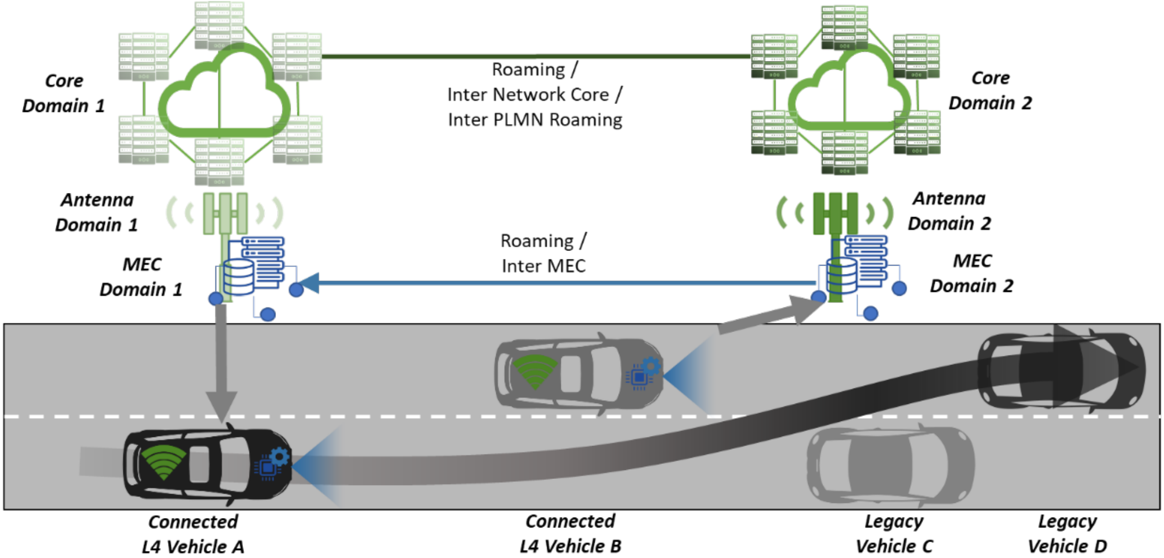

Figure 23 Extended sensors with Collective Perception Messages

The objective of this user story is to enhance the environmental perception of vehicles by enabling the real-time data exchange between vehicles and RSU. AD vehicles with Level 4 capability require predictive information of environment sufficiently ahead in time. AD vehicles are equipped with on-board sensors, however, with limited range to detect objects and obstacles. CPE extends this range by providing perception of areas not visible to the vehicle sensors due to curves, corners or obstacles in the roads. AD vehicles equipped with 5G technology could share raw sensor data from cameras, LIDAR, etc. or share pre-processed data such as dynamic objects and planned trajectories as the Collective Perception Message (CPM). Additionally, other driving condition data such as weather situation and traffic information can be shared. gNodeB can act as a hub to relay pre-processed data in low resolution or raw data in high resolution, or (in case of MEC) combined data from different vehicles. Exchanging high resolution perception data in real-time requires high bandwidth and low latency communication as promised by 5G (eMBB, uRLLC).

In the NL trial, CPE will be evaluated in a cooperative merging scenario at the on-ramp from Nuenen to A270 motorway on the route from Helmond to Eindhoven. Traffic information from the roadside sensors (fixed cameras from SISSBV) will be utilized for a safe merging scenario. There are two connected vehicles in this scenario. The first vehicle is driving from Helmond on A270 and arriving close to the on-ramp from Nuenen while the second vehicle is driving from Nuenen and is arriving close to the ramp to finally merge in the A270. The second vehicle has no information about the traffic situation on the A270 due to its limited field-of-view. The vehicles are connected to two different networks; namely KPN and TNO. Both vehicles send requests to their respective gNodeBs to obtain each other's environmental information. Collective Perception Service aggregates/fuses CPM messages from vehicles and roadside sensors. The gNodeBs send aggregated CPM messages from the Collective Perception Service to the vehicles. Both vehicles will therefore be aware of each other's presence and anticipate on it accordingly. When in proximity vehicles also receive CPM messages over C-V2V. Upon request, vehicles can ask for more detailed data about a region, by exchanging pre-processed or raw sensor. The second vehicle can now evaluate and determine its merging possibilities in real time considering safety and traffic situation. When the second vehicle is on the on-ramp, it sends its decision to the first vehicle to make it aware about its merging action. Hence, a safe and efficient merging manoeuvre can be achieved using CPE and exploiting the capabilities of 5G.

7.3.4.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 31 Issues coverage of the Extended Sensors User Story #4 (NL).

Category	ID	Issue name
Telecommunications	TR2	SA Roaming Latency
	TC2	Performance Continuity
Application	AC1	V2X Continuity
Regulation	RC3	Sensor Compliance
Regulation	RN1	Neutrality regulation

7.3.4.2. Uniqueness and relevance of the user story implemented at the local site

- Only User Story of this category **addressing V2X Continuity, SA Roaming Latency and neutrality regulation cross-border issues.**
  - Tests of performance continuity with handover between PLMNs.
  - Assessment of the impact of V2X discontinuity in the safety assessment.
  - Tests of message exchange between different edges for optimizing volume of messages based on actual requests.
- **Use of CPM messages.**

7.3.4.3. Portfolio of transferable assets

Table 32 Overview of the tangible assets that can be transferred to the CBC from Extended Sensors US#4

Target CBC	ES-PT
List of assets to be transferred to the CBC	• Slicing setup with SA core. ◦ Investigate how slicing will work in a X-border scenario

	- Design slices incorporating slices for 1. video, 2. V2X messages and 3. other data (mostly log data) - Design and test out the different parameters with the requirements for latency, bandwidth, etc. - Performance continuity with handover to different MNO using either static or dynamic setup. • Service discovery with multiple MEC's, SSC and LADN. - Get the vehicle connected to the best message exchange compared to the overall latency. - Integration between message exchange, in vehicle application and 5G network. • Message exchange: - MQTT-based IoT messaging using geolocation-based topics (similar to Concorda, intercor and Dutch talking traffic). - Mechanism for optimizing volume of messages inter-edge. • Handover optimizations with 5G Core
Other stakeholders interested on the offering	• Automotive industry & suppliers (OBU, mapping companies) • MNOs & suppliers • Road traffic management center • Ministries of Traffic, Transport and Communications and relevant government agencies • Highway operators • Municipality of Helmond: testing with AD vehicles on public roads

8. UC CATEGORY 4: REMOTE DRIVING

8.1. Description

According to 3GPP TS 22.186 R16, Remote Driving "enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. For a case where variation is limited, and routes are predictable, such as public transportation, driving based on cloud computing can be used. In addition, access to cloud-based back-end service platform can be considered for this use case group".

In 5G-MOBIX there are five user stories described under the category of Remote Driving:

Table 33 User Stories under Remote Driving UC category

Remote Driving User Story	Location
Automated shuttle remote driving **across borders**	Spain-Portugal (ES-PT) cross-border corridor
Remote driving in a **redundant network** environment	Finnish (FI) trial site
Remote driving using **5G positioning**	Dutch (NL) trial site
Remote driving with **data ownership** focus	Chinese (CN) trial site
Remote driving using **mmWave communication**	Korean (KR) trial site

In the following section, the main cross-border challenges addressed by these user stories are identified. Then, each of these user stories are described. In the case of user stories not implemented in a cross-border corridor, their tangible contributions to the corresponding cross-border corridor are described and justified.

More information about these user stories can be found in Annex 3.

8.2. Cross-Border Impact

In the next table, the main technical challenges and issues targeted under this use case category are summarised. The issues targeted by a single trial site are marked in the table with thicker borders.

Table 34 Issues coverage from Remote Driving.

Category	ID	Issue name	ES-PT	FI	NL	CN	KR
Telecommunications	TR1	NSA Roaming Latency					
	TR2	SA Roaming Latency					
	TH1	Hybrid Handover Latency					
	TC1	Continuity Protocol					
	TC2	Performance Continuity					
Application	AC1	V2X Continuity					
	AG1	Accurate Geo-Positioning					
	AP1	Real-time Multi-tier Processing					
Security & Data Privacy	SO1	Data Ownership					
Regulation	RC1	Autonomous Vehicle regulation Compliance					
	RN1	Neutrality regulation					

8.3. User stories

8.3.1. User Story #1 Automated shuttle remote driving across borders (ES-PT)

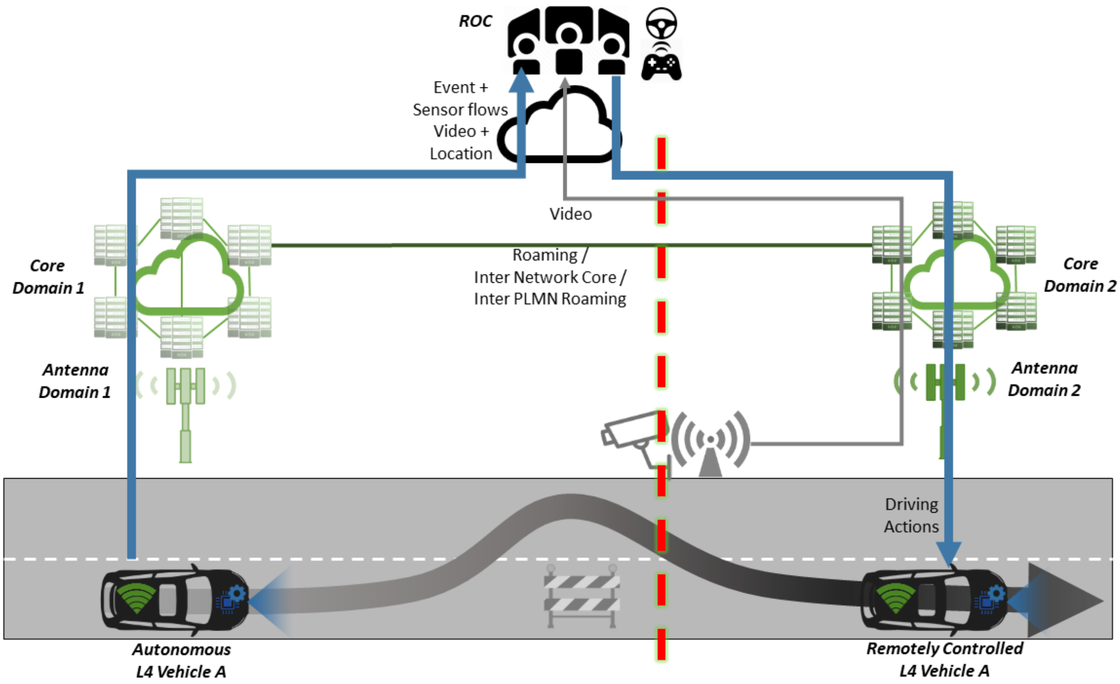

Figure 24 Automated shuttle remote driving across borders

This use case is focussed in the deployment of last mile EV Automated shuttle vehicles in different environments:

- Cross Border environment: The shuttle will cover a route between Spain and Portugal connecting the cities of Tui and Valença through the old international bridge.
- Urban environment: The shuttle will cover a route in the city of Vigo.

For both environments, we will consider these two scenarios:

- **Scenario 1: Cooperative automated operation:** In this scenario, the EV Autonomous shuttle is able to receive information coming from other actors (like a Vulnerable Road User) and adapt its behaviour according to specific needs.
- **Scenario 2: Remote Control:** In this scenario the EV autonomous vehicle is driving following a predefined route, and suddenly an obstacle appears in its path blocking the original route. In this situation, an operator is alarmed, and he/she is able to remotely take the control of the EV autonomous vehicle or issue a set of new navigation commands in order to handle a new route.

8.3.1.1. Addressed cross-border issues

Table 35 Issues coverage from of the Remote Driving User Story #1 (ES-PT).

Category	ID	Issue name
Telecommunications	TR1	NSA Roaming Latency
	TC1	Continuity Protocol
Application	AC1	V2X Continuity
	AP1	Real-time Multi-tier Processing
Regulation	RC1	Autonomous Vehicle regulation Compliance
	RN1	Neutrality regulation

8.3.2. User Story #2 Remote driving in a redundant network environment (FI)

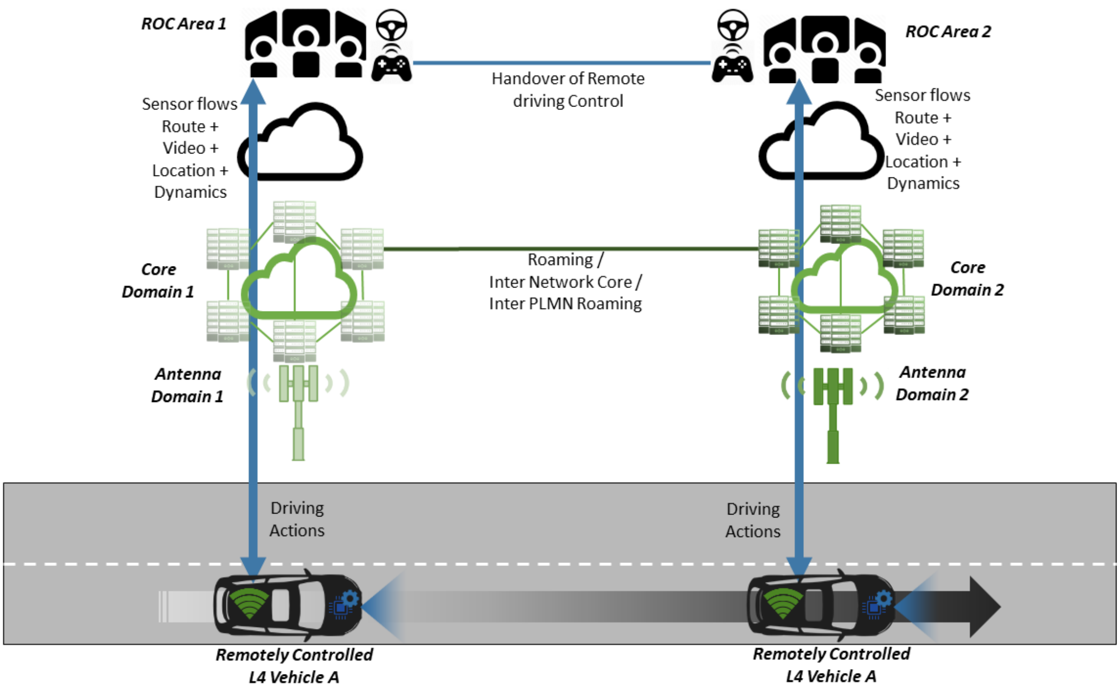

Figure 25 Remote driving in a redundant network environment

The remote driving of an SAE L4 vehicle is enabled by a V2N connection between the vehicular Onboard Unit (OBU) and a remote server hosting V2N applications, in this case the remote driving application is used by the remote human operator. The V2N connection transfers the sensor data feed (high resolution perception data) from the vehicle to the remote human operator (in the uplink direction). The sensor data provides the human operator a "driver's view" allows the human operator to send appropriate command messages (e.g. command trajectories) back to the L4 vehicle (in the downlink direction).

The remote control/driving of vehicle presents stringent requirements on connection between the vehicle and the Remote Operations Centre (ROC). These requirements include the need to ensure that human operator always maintains connectivity to the vehicle they control, the latency minimized to ensure timeliness of the downlink control messages from the human operator; and the uplink capacity is guaranteed for the transmission of the sensor data feeds from the vehicle. The whole control loop needs to keep tight. The accumulated delay from: sensor reading, sensor data processing, uplink, data visualization, manual control, control signal reading, downlink, and control signal processing to control must be kept low for direct control (depending on speed and dynamics of the vehicle). Furthermore, the vehicle should be aware of any latency issues, so that the operational speed could be adjusted accordingly.

Remote driving (and other V2X use cases) will occur in multi-operator scenarios in legacy 4G [3GPP TR 36.885][4] and future 5G [3GPP 38.885][5] contexts, whereby, the L4 vehicle trajectory is an area covered by multiple public land mobile networks (PLMNs) or transitions between two PLMN coverage areas.

The remote driving user story also underlines safety aspects and need for the L4 vehicle to maintain reliable/uninterrupted V2N connectivity. In practice, a vehicle's home PLMN (original serving network) may have locations with poor or non-existent coverage, or then experience V2N connection degradation or failure due to overloading, network failure etc. To guarantee availability V2N connectivity for critical L4 vehicle services (such as, remote driving), the possibility of the vehicle to seamlessly switch to (or simultaneously utilise) a visited PLMN ensures safer operation of the vehicle regardless of instantaneous network conditions.

8.3.2.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 36 Issues coverage of the Extended Sensors User Story #2 (FI).

Category	ID	Issue name
Telecommunications	TR1	NSA Roaming Latency
	TH1	Hybrid Handover Latency
Application	AC1	V2X Continuity

[4] 3GPP TR 36.885, "Study on LTE-based V2X Services" June, 2016
[5] 3GPP TR 38.885, "NR; Study on Vehicle-to-Everything" March, 2018

8.3.2.2. Uniqueness and relevance of the user story implemented at the local site

- CBC focus has been on roaming between two PLMNs (inter-PLMN, rather than multi-PLMN scenario), but there is noted interest to evaluate multi-PLMN approach in areas with overlapping x-border network coverage. The **redundant multi-PLMN approach** is an original feature of Finland's user story.

8.3.2.3. Portfolio of transferable assets

Table 37 Overview of the tangible assets that can be transferred to the CBC from Remote Driving US#2

Target CBC	ES-PT
List of assets to be transferred to the CBC	• **MEC functionalities**. This will reduce FI's contribution integration complexity. It will include features developed and evaluated in FI: (1) Multi-PLMN Edge computing service discovery/registration/migration: Differently from the current static ES-PT discovery/registration approach, the FI one is dynamic: the application registers the vehicle (and/or its tasks) to a coordinator (The coordinator is a manager program that monitors the capacity and the usage of all MECs in the local area. Each area, e.g. a district like Otaniemi, has only one coordinator). The coordinator allocates MECs to the vehicle based on the MECs' available capacity, on the requested tasks' quality demand or on the network connectivity. The vehicle has no visibility of the MEC resources but the vehicle requirements could be registered to the coordinator and the mapping from vehicle to MEC can be done during registration. It could be used in ES-PT for MEC (as gateway) discovery/registration, streaming video or caching tasks. (2) Crowd-sensing platform with pub/sub-based data collection support from vehicles and sensor infrastructures: (3) It runs in the MEC and CLOUD, but we do it in the MEC. It collects primarily video and sensor data from the vehicles. It could be used in ES-PT for vehicle's status monitoring or HD surveillance video upload. Besides, it supports 'dynamically invoking remote sensors. The coordinator has a global view of all vehicles and can control the video upload actions in a centralized way. • **Multi-PLMN solution**. FI will coordinate with FR to provide an alternative 2 PLMN possible implementation so that together with FR they will be able to test different scenarios in the CBC (5G-4G

	transitions, for instance). FR Vehicle's OBU will test a different handover scenario using two PLMNs – a soft handover (connection with two SIM cards) experiment to compare with the other implementations with only on SIM card using home routed or local breakout, for instance.
Other stakeholders interested on the offering	• Local regulator (TRAFICOM) on the FI site advisory board has expressed interest to have testing of the multi-PLMN scenario to inform policy discussions

8.3.3. User Story #3 Remote driving using 5G positioning (NL)

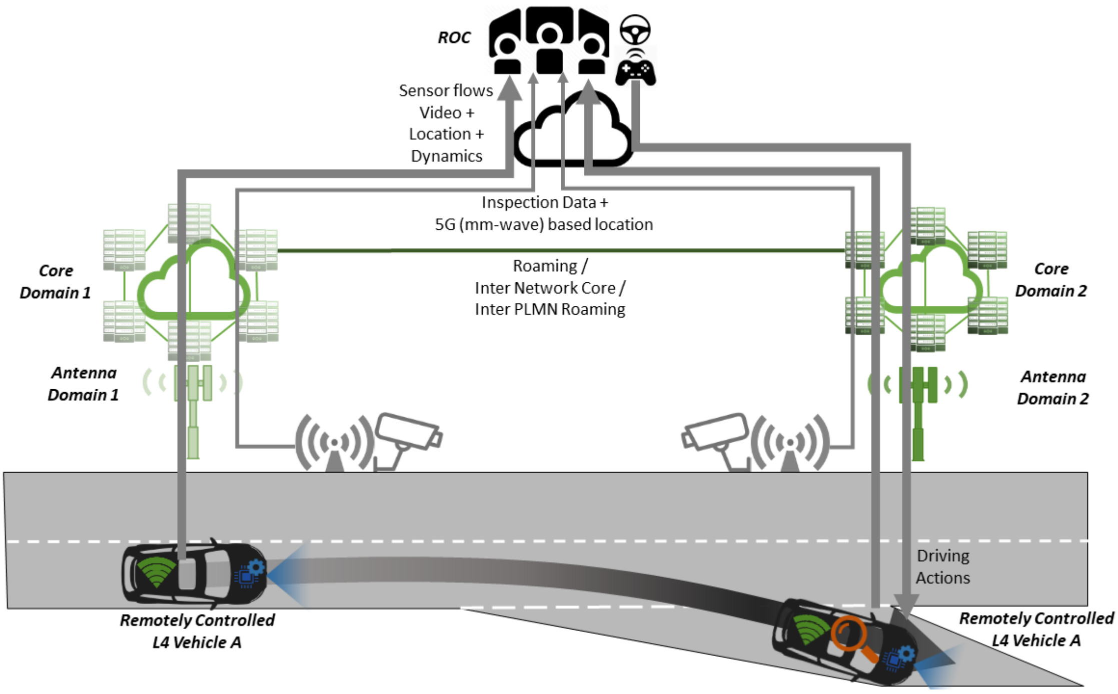

Figure 26 Remote driving using 5G positioning

In situation where the AD vehicle is unable to automatically drive further (due to a failure or unexpected driving condition), a remote operator takes over control of the vehicle and drives it to a point where AD can be resumed. As an example, this can be in situations like border control, construction zones and inclement weather. To tele-operate a vehicle, the data from multiple sensors should stream their information (synchronised and with low latency) to the operator and at the same time have low latency in the control task of manoeuvring the vehicle in real time.

One example for tele-operation is when an AD vehicle is automatically manoeuvred to a bay/slot assigned by border control remotely/via 5G and local edge computing for monitoring actions of the autonomous car by the border agents. For automated manoeuvring in a complex border-post environment, precise localization (of the car in surroundings by the car, plus potentially of the car by the infrastructure) is needed. In the NL trial, tele-operation will be tested by driving the vehicle from the emergency lane to an assigned slot on a rest area along the A270. However, testing of localization services will be carried out at the TU/e campus as it needs special infrastructure, e.g., fibre optical backbone and multiple 5G small cells, available at the TU/e campus for high accuracy localisation services and low latency. New 5G technology based on adaptation and integration of 5G beam steering and MIMO will be used for localization and positioning. The 5G (mm-wave) based location can serve as a redundant localization system and useful in scenarios such as border customs control with gates with a roof covering.

8.3.3.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 38 Issues coverage of the Remote Driving User Story #3 (NL).

Category	ID	Issue name
Telecommunications	TR2	SA Roaming Latency
	TC2	Performance Continuity
Application	AC1	V2X Continuity
	AG1	Accurate Geo-Positioning
	RN1	Neutrality regulation

8.3.3.2. Uniqueness and relevance of the user story implemented at the local site

- Tests mmwave vs. sub-6 frequencies for extended future 5G capabilities:
  - Test **localization of vehicle over 5G** and test different frequency bands: ie. 3.5 GHz and 26 GHz. Use of localization algorithm that is able to switch between both in optimal way (also on more commonly available frequency bands).
  - Test different modalities of localization in a degradation of sensors, using **mmwave localization** as one of the options (next to GPS, odometry, visual odometry etc.)
  - Test mm-wave capacity boost in remote driving use case: reduced interference, more viable connection.
- One remote station & 2 PLMNs using virtual environment for development and virtual remote control (others only focus on human in the loop).

- Multiple remote drivers with consoles connected to different MECs taking over control of the vehicle, independently from handover between PLMNs.

8.3.3.3. *Portfolio of transferable assets*

Table 39 Overview of the tangible assets that can be transferred to the CBC from Remote Driving US#3

Target CBC	ES-PT
List of assets to be transferred to the CBC	• Virtual remote control (depends on integration with cross border site) • Fleet management system to organize control of vehicle between different human and virtual operators.
Other stakeholders interested on the offering	• Dutch ministry of Infrastructure and Water Management has already expressed an interest in remote driving trucks

8.3.4. User Story #4 Remote driving with data ownership focus (CN)

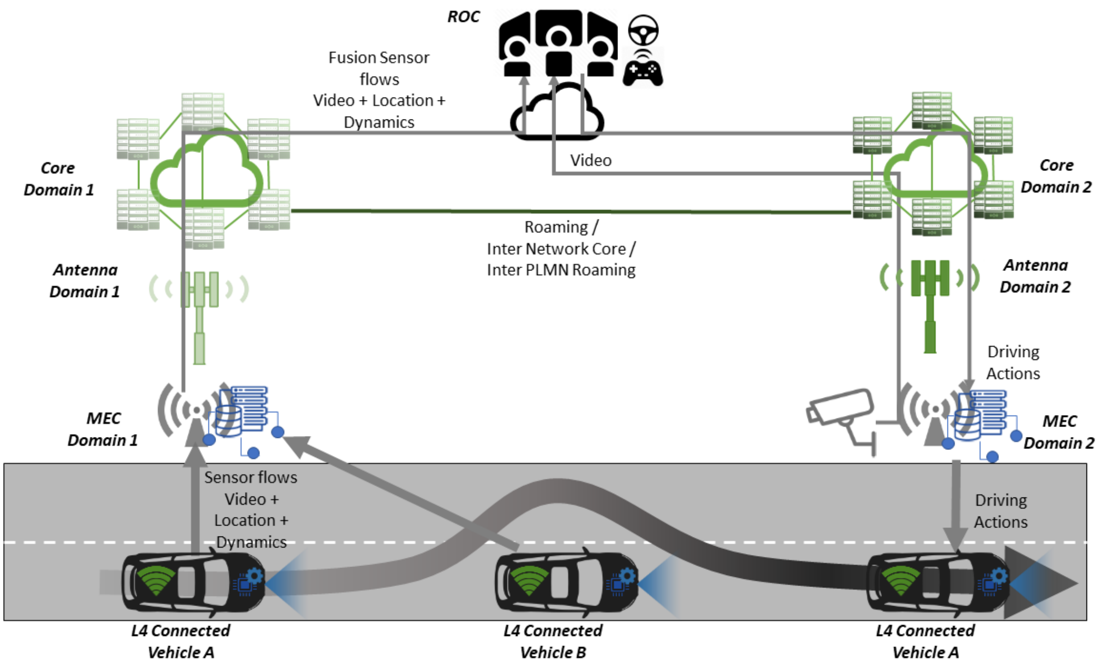

Figure 27 Remote driving with data ownership focus

In the China test site, the control centre plays an important role to remotely control the autonomous subject vehicle (Vehicle A), autonomous test vehicle (Vehicle B) and Pedestrian C to complete the networking performance testes of connected vehicles. The control centre first plans the scheme and then sends the global path information to Vehicle B through RSU. During the experiment, subject vehicle A communicates with RSU via V2I and with test vehicle B via V2V. After obtaining real-time information, local path planning will be carried out to complete the plan. After the test, Vehicle A notifies the control centre and uploads various data to the cloud server.

8.3.4.1. Addressed cross-border issues

This user story is mainly focused on addressing the data ownership cross-border issue.

Table 40 Issues coverage of the Remote Driving User Story #4 (CN).

Category	ID	Issue name
Security & Data Privacy	SO1	Data Ownership

8.3.4.2. Uniqueness and relevance of the user story implemented at the local site

- This user story is the only one **addressing the data ownership issue** or technical challenge.
- **Multi C-V2X scenario**:
  - Vehicle moves from area 1 covered by 5G to area 2 covered by LTE-V without 5G, which enables remote driving to achieve cross-network handover.
  - Vehicle remote controller helps 5G to LTE-V conversion.
  - Under different networks, the uplink and downlink data need to be processed differently, and the data format is changed under LTE-V, such as video.
- **Challenging trial scenes** (tunnel, bridge, long steep slope, ramp, toll station).
- Two MNOs (China UNICOM, China MOBILE) with two vendors (ZTE, HUAWEI) are present.
- The topography and landform condition are ideal for evaluation of 5GMOBIX CCAM.

8.3.4.3. Portfolio of transferable assets

Table 41 Overview of the tangible assets that can be transferred to the CBC from Advanced Driving US#4

Target CBC	ES-PT
List of assets to be transferred to the CBC	• The 5G remote driving controller. • The control center display screen. • Specifications for assuring data ownership in a remote driving data flow.

Other stakeholders interested on the offering	• 5G equipment Supplier: HUAWEI, ZTE • Self-driving technology company: SDIA, CNHTC • MNOs: China UNICOM, China MOBILE • Road infrastructure contractor: QLTD • Traffic management department: QLTD

8.3.5. User Story #5 Remote driving using mmWave communication (KR)

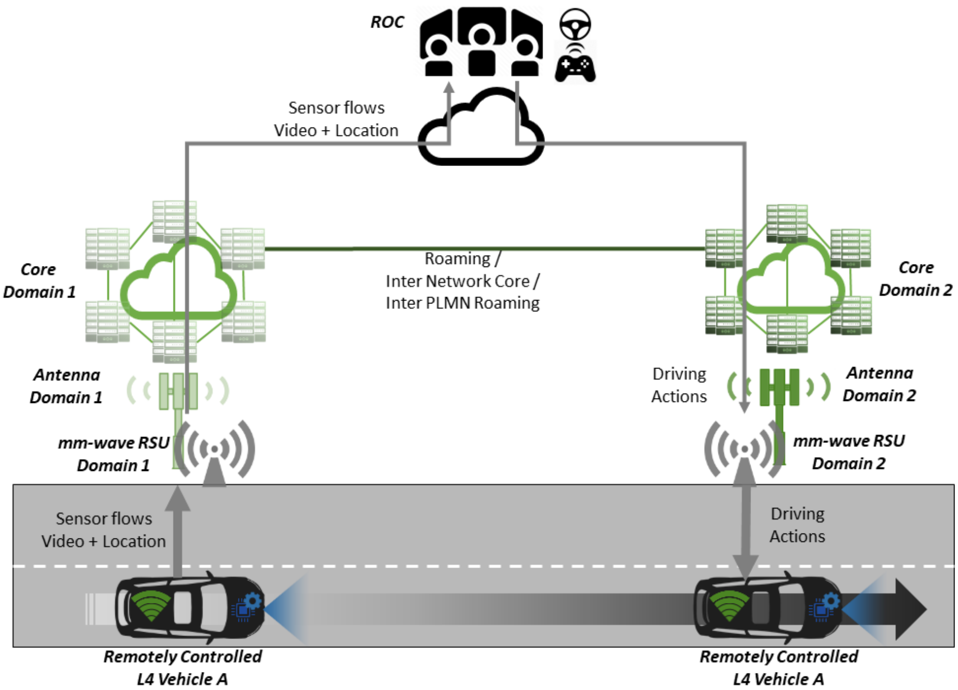

Figure 28 Remote driving using mmWave communication

Remote driving use case enables remote operator to access the right of control in case of automated vehicle in under malfunction or driver is in accident. The most important factors for realizing remote driving should comprise the following: Ensuring enough field of view and high definition of view for front camera, ultra-low latency to sharing live video stream between vehicle equipped cameras and remote site, and reliable connectivity to control remote driving vehicle in remote site. Consequently, remote driving vehicle needs to be shared not only driving information like speed, position, and videos (front, right and left side, and rear), but also vehicle status information like steering angle, gear position, throttle pedal position, and fuel consumption with remote operator. The driving and status information provided by the remote driving vehicle should be transmitted to the human operator at the remote site with ultra-low latency. In order to sharing high definition live video stream data with remote site in real-time, very high up-link data rate should be required and it will be realised by 5G network. At the same time, the control data to driving remote vehicle should be generated by human operator at the remote site and be streamed to the remote driving vehicle through down-link with low latency.

An emergency stop function of the remote driving vehicle should be enabled automatically when the connectivity is unstable between remote driving vehicle and remote site, thereby achieving more reliable and robust safety.

As a deployment scenario for remote driving use case, remote driving vehicle has a connectivity to the 5G network through a base station (BS) including microcell BS, and BS-type road side unit (RSU). In-vehicle UE that is equipped in the remote driving vehicle will provide the connectivity to the 5G network by connected with RSU.

The remote driving use case generally supports eMBB 5G-service to stream raw sensor and high definition video data from remote driving vehicle to remote site. Hence, it intrinsically requires high data throughput up to several Gbps. It also supports URLLC 5G-service to exchange safety critical message.

8.3.5.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 42 Issues coverage of the KR Remote Driving user story.

Category	ID	Issue name
Telecommunications	TH1	Hybrid Handover Latency
Application	AC1	V2X Continuity
	AG1	Accurate Geo-Positioning

8.3.5.2. Uniqueness and relevance of the user story implemented at the local site

- The use case aims to validate feasibility of remote driving system based on mmWave-band V2I communication. Since mmWave frequency is higher than 5G frequency in CBC, it is expected that Its performance far superior to the other existing remote-control user stories in terms of data rate and latency.
- The user story is focusing on 4 real time video stream (front, left side, right side, and rear) that is required high data rate uplink communication supporting system bandwidth up to 1GHz. In order to provide stable high data rate uplink wireless connectivity, **mmWave-band V2I communication** will be implemented.
- Only KR partners are developing remote vehicle user story based on 5G NR-based V2I/N system operating at a mmWave band (22~23.6 GHz).

8.3.5.3. Portfolio of transferable assets

Table 43 Overview of the tangible assets that can be transferred to the CBC from Advanced Driving US#5

Target CBC	ES-PT
List of assets to be transferred to the CBC	• Test results and insights from mmWave V2I communication implementation. • Remote driving system based on WLAN (802.11 a/b/g@2.4GHz) already implemented and tested.
Other stakeholders interested on the offering	• 5G equipment vendors • Tier 1s and OEMs • MNOs • Road infrastructure operators

9. UC CATEGORY 5: VEHICLE QUALITY OF SERVICE SUPPORT

9.1. Description

According to 3GPP TS 22.186 R16, Vehicle quality of service support "enables a V2X application to be timely notified of expected or estimated change of quality of service before actual change occurs and to enable the 3GPP System to modify the quality of service in line with V2X application's quality of service needs. Based on the quality of service information, the V2X application can adapt behaviour to 3GPP System's conditions. The benefits of this use case group are offerings of smoother user experience of service".

In 5G-MOBIX there are three user stories described under the category of Vehicle Quality of Service Support:

Table 44 User Stories under Vehicle QoS Support UC category

Vehicle QoS Support User Story	Location
Public transport with **HD media services** and **video surveillance**	Spain-Portugal (ES-PT) cross-border corridor
QoS adaptation for security check in hybrid V2X environment	French (FR) trial site
Tethering via vehicle using **mmWave communication**	Korean (KR) trial site

In the following section, the main cross-border challenges addressed by these user stories are identified. Then, each of these user stories are described. In the case of user stories not implemented in a cross-border corridor, their tangible contributions to the corresponding cross-border corridor are described and justified.

More information about these user stories can be found in Annex 3.

9.2. Cross-Border Impact

In the next table, the main technical challenges and issues targeted under this use case category are summarised. The issues targeted by a single trial site are marked in the table with thicker borders.

Table 45 Issues coverage from User Stories of Vehicle QoS support.

Category	ID	Issue name	ES-PT	FR	KR
Telecommunications	TR1	NSA Roaming Latency			
	TH2	Low coverage Handover			
	TC1	Continuity Protocol			
	TN2	Hybrid Networking			
Application	AC1	V2X Continuity			
	AC2	Dynamic QoS Continuity			
	AP2	On-demand Processing			
Security & Data Privacy	SP1	Data Privacy			
	SO1	Data Ownership			
Regulation	RC1	Autonomous Vehicle regulation Compliance			
	RL	Law enforcement interaction			

9.3. User stories

9.3.1. User Story #1 Public transport with HD media services and video surveillance (ES-PT)

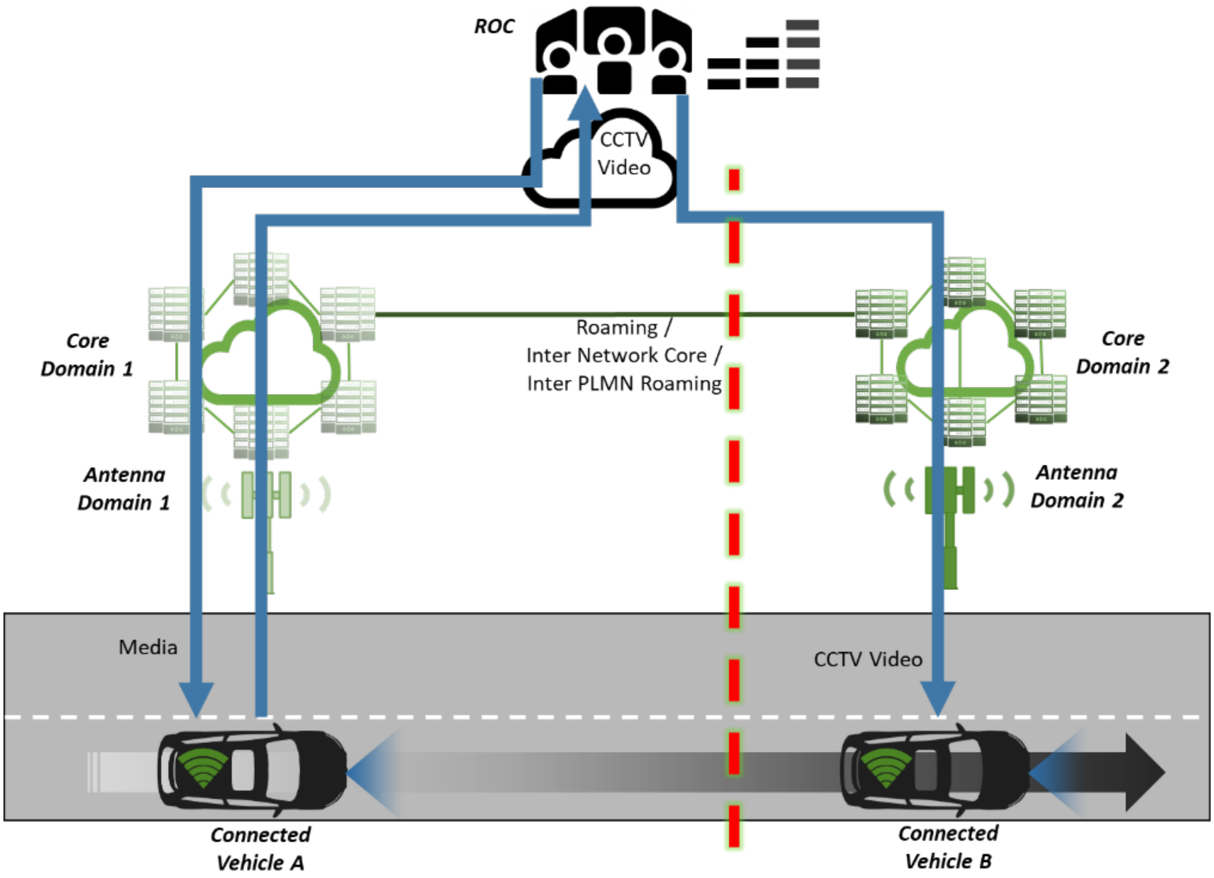

Figure 29 Public transport with HD media services and video surveillance

The objective of this use case is to provide real time connected services to the public transport fleet that connects the cities of Vigo and Porto (considering the way to the Francisco Sá Carneiro airport). According to this approach, users will be able to enjoy different multimedia services while travelling in the public transport, including high bandwidth data consumption applications as well. On the other hand, the public transport vehicle will be equipped with a 4K Camera in order to be able to remotely access the video stream for Control Centre management and monitoring tasks. Added to this, in vehicle sensor data will be sent to the ITS Centre in order to update the HD maps of other vehicles around, helping to improve the execution of autonomous driving manoeuvres in terms of safety and comfort.

The Use Case can include a multimedia device which will be used as user interface, allowing users to make use of the multimedia application installed on this device.

Another option is to allow users to connect their own devices through a Wi-Fi connection which will be connected to the high capabilities mobile network.

These options will be studied and decided during the deployment of the use case.

4K Front camera and in vehicle sensors will be connected to the communication unit, opening the stream channel from the bus to the ALSA Control Centre and the ITS Centre. ALSA, as the public transport operator, will have the remote connection to the 4k camera stream in order to visualize the image of where the vehicle is passing by.

9.3.1.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 46 S of the QoS Support User Story #1 (ES-PT).

Category	ID	Issue name
Telecommunications	TR1	NSA Roaming Latency
	TC1	Continuity Protocol
Application	AP2	On-demand Processing
Regulation	RC1	Autonomous Vehicle regulation Compliance

9.3.2. User Story #2 QoS adaptation for Security Check in hybrid V2X environment (FR)

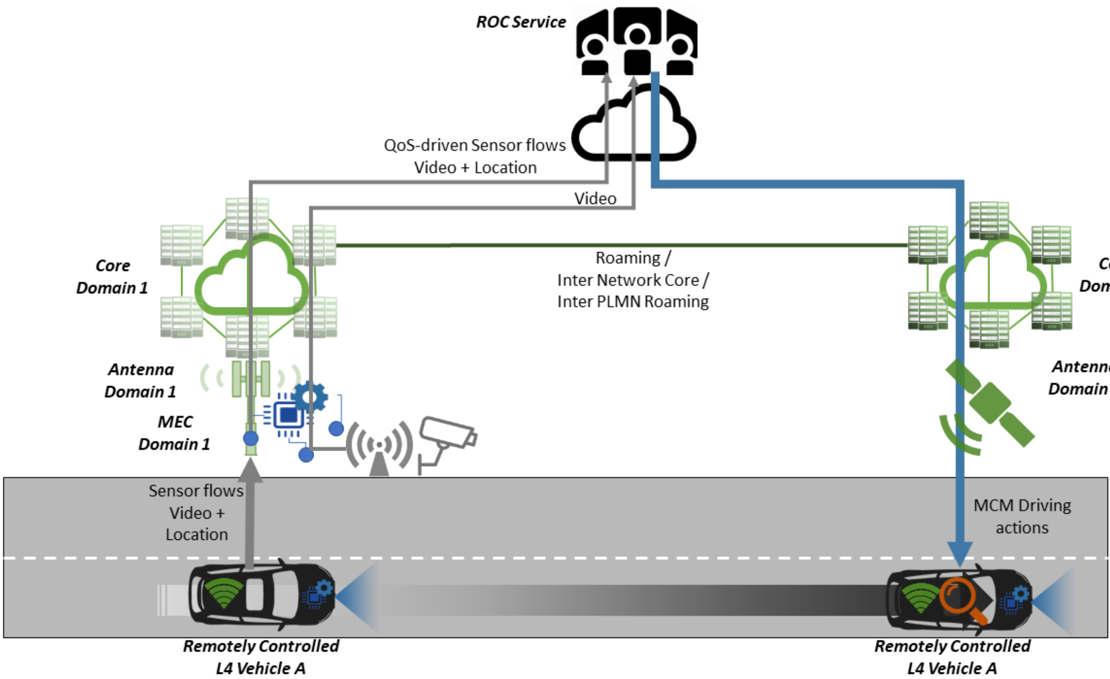

Figure 30 QoS adaptation for security check in hybrid V2X environment

The present use case deals with a situation where a suspicious vehicle is detected by a police car on the road. Upon reception of a CAM message of the vehicle, the police car obtains its short-terms certificate. With this information, the police can then request Public Key Infrastructure (PKI) authority to provide it with the Vehicle Identification Number (VIN) and other important information (IP address) necessary for a security check, and then notifies this information to the police centre. Upon reception of VIN, the police centre checks the database for different records such as criminal record concerning the vehicle. Furthermore, the police centre can perform real-time security control/tracking by requesting roadside sensor data from MEC1 as well as sensor and camera data from the vehicle.

Vehicle A starts to stream its camera video to the police centre according to the current link quality. Meanwhile, the vehicle is crossing the border, network and application handover procedures have to be executed. At the application level, security check will be continued by the police centre 2. At the network level, a change of access network is needed. Depending on the mounting positions of the eNodeB/gNodeBs and also the types of the networks, the user may experience different issues such as a coverage gap or a sudden degradation of communication quality. In order to ensure the continuous security check, the vehicle shall perform soft handover to the prioritized available network technology according to a priority-based network selection algorithm. MEC predictive QoS support could also be used to provide Handover time prediction and QoE optimization in order to maintain the service continuity. This requires from MEC to provide the Radio Network Information Service (RNIS) which relies on the Network Exposure Function (NEF) from 5G network. This latter's role is to expose capability information and services of the 5G Core/Radio Network Functions to external entities such as MEC, especially for the up to date radio information related to UEs.

Once seamless Handover is performed, the vehicle adjusts its transmission parameters (data type, data size, transmission rate, etc), by taking into account the QoS change of the network link.

The vehicle tracking can be followed by manual security control by the police. To do so, the police instructs the vehicle to stop in a safe area by transmitting Manoeuvre Coordination Message (MCM).

This use case is carried out at UTAC/CERAM closed site where it will be tested on a highway circuit. A multi technology telecom operator at the site (Orange 5G, Bouygues 4G and CATAPULT satellite communications) will allow to emulate the hybrid environment and QoS conditions change while the police authority is taking control over the vehicle.

9.3.2.1. Addressed cross-border issues

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 47 Issues coverage of the Vehicle QoS Support User Story #2 (FR).

Category	ID	Issue name
Telecommunications	TH2	Low coverage Handover
	TN2	Hybrid Networking
Application	AC1	V2X Continuity
	AC2	Dynamic QoS Continuity
Security & Data Privacy	SP1	Data Privacy
	SO1	Data Ownership
Regulation	RC1	Autonomous Vehicle regulation Compliance
	RL1	Law enforcement interaction

9.3.2.2. Uniqueness and relevance of the user story implemented at the local site

- FR site is the unique site to focus on **infrastructure-based perception** (raw data-based perception).
- FR site is the unique site **considering coverage gap and hybrid network connectivity** (4G/5G/Sat) and hence developing seamless handover procedure and data adaptation when network conditions change.

- CBC are using the data provided by the vehicle to do monitoring; FR site enriches the data with infrastructure information
- CBC are considering that 5G will be available all the time, and then no need to switch to other technology
- FR site considers
  - CBC scenario network coverage gap can occur or
  - usage of different generations of cellular technologies are necessary

then **QoS and connection continuity must be granted for security check**

9.3.2.3. Portfolio of transferable assets

Table 48 Overview of the tangible assets that can be transferred to the ES-PT CBC from QoS Support US#2

Target CBC	ES-PT
List of assets to be transferred to the CBC	• Seamless Handover pre-test on the vehicle side (5G to 4G, 4G to 5G, 5G to 5G, 5G to sat, etc.) with data DL and UL • QoS adaptation for UL video stream to network
Other stakeholders interested on the offering	• Law enforcement • Road operator • Vehicle provider /OBU provider

Table 49 Overview of the tangible assets that can be transferred to the GR-TR CBC from QoS Support US#2

Target CBC	GR-TR
List of assets to be transferred to the CBC	• Encoding and Decoding functionality for Video Streaming Applications
Other stakeholders interested on the offering	• Law enforcement • Vehicle provider /OBU provider

9.3.3. User Story #3 Tethering via vehicle using mmWave communication (KR)

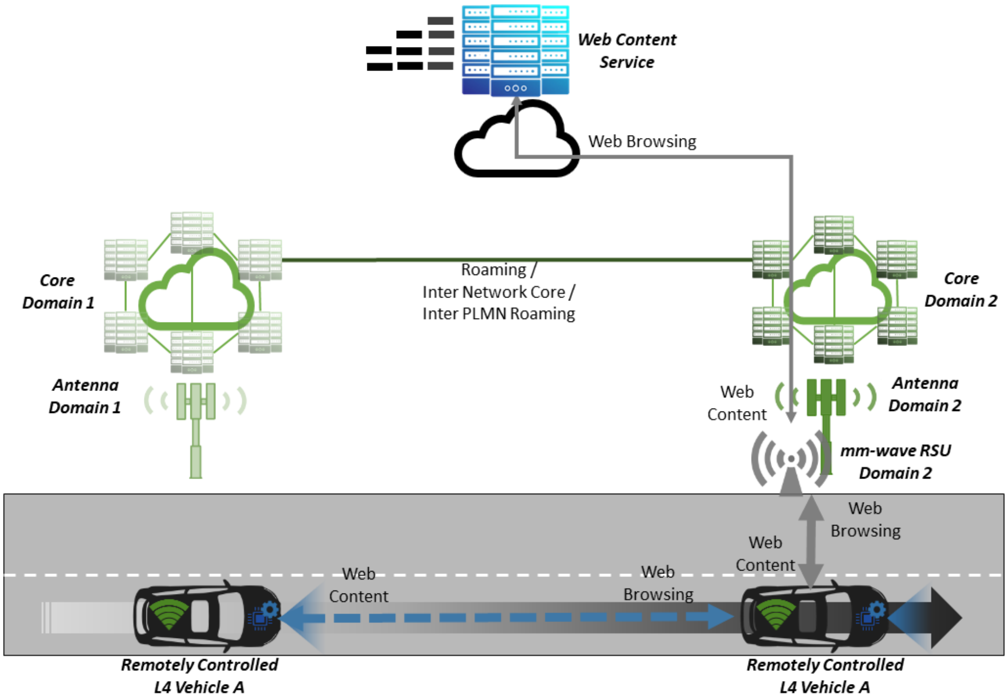

Figure 31 Tethering via vehicle using mmWave communication

Tethering via Vehicle use case enables in-vehicle UEs and pedestrian UEs to access the network with the help of a vehicle relay which is deployed at a vehicle. For in-vehicle UEs, through Tethering via Vehicle use case, it is possible to avoid high penetration loss occurring from the metallic vehicle surface, thereby achieving more reliable wireless connectivity as well as reduced UE power consumption. The in-vehicle UEs are also benefited from the minimized handover operations. Only the vehicle relays involve in the handover operations. For pedestrian UEs, tethering via Vehicle use case enables more reliable connectivity, increased throughput and reduced UE power consumption since it reduces the communication range of the pedestrian UEs.

As a deployment scenario for Tethering via Vehicle use case, a vehicle relay can have the Internet connectivity to the network through a base station (BS) including macrocell BS, microcell BS, and BS-type road side unit (RSU). Another UE such as UE-type RSU can also provide the Internet connectivity to the network. Non-terrestrial links such as satellite BS, satellite relay, and high-altitude platform (HAP) can also be used to provide the Internet connectivity to the network.

Tethering via Vehicle use case generally supports eMBB-type services such as web surfing, FTP, and video streaming. Hence, it intrinsically requires high data throughput up to several Gbps. In order to satisfy such very high throughput, large bandwidth is necessary which is quite difficult in lower frequency bands below 6 GHz. Therefore, mmWave frequency band should be employed to support such high throughput and to satisfy the Tethering via Vehicle use case.

9.3.3.1. *Addressed cross-border issues*

This user story is focused on addressing the following cross-border issues or technical challenges:

Table 50 Issues coverage of the QoS Support User Story #3 (KR).

Category	ID	Issue name
Telecommunications	TH2	Low coverage Handover
Application	AC1	V2X Continuity

9.3.3.2. *Uniqueness and relevance of the user story implemented at the local site*

- The user story is **focused on providing high data rate WiFi service inside a vehicle** including public transportation like a bus. In order to support such in-vehicle wireless connectivity, mobile backhaul link between base stations installed along the road and onboard terminals deployed at a vehicle will be implemented and tested.
- Broadband onboard connectivity is enabled by **mmWave-band 5G NR V2I/N communications** supporting system bandwidth of up to 1 GHz. This user story aims to validate feasibility of mmWave-band V2I/N communications by showcasing a variety of onboard mobile services and its performance far superior to the other existing V2X communications in terms of data rate and latency.

9.3.3.3. *Portfolio of transferable assets*

Table 51 Overview of the tangible assets that can be transferred to the CBC from QoS Support US#3

Target CBC	ES-PT
List of assets to be transferred to the CBC	• Technical report evaluating the feasibility of mmWave-band V2I/N communications after testing a variety of onboard mobile services.
Other stakeholders interested on the offering	• There may be strong interest in public sectors including local government in that citizens using public transportation can be benefited from the onboard public WiFi service. • Public transportation operators can also have strong interest since it can provide advanced onboard services to the passengers. • Wireless equipment vendors can also have strong interest considering the attractiveness of the new market opportunity.

10. 5G-MOBIX USE CASES OVERVIEW

In 5G-MOBIX there are five use case categories, defined by 3GPP TS 22.186: Advanced Driving, Vehicles Platooning, Extended Sensors, Remote Driving and Vehicle QoS Support. Under these categories, different user stories have been classified. The following table shows the first iteration of this classification. Some user stories fall into two categories, as they have elements of both categories. However, a main category has been defined for each user story. In this document, user stories are then organised in chapters according to this main category. The user stories planned at cross-border corridors cover all categories. The user stories planned at local trial sites are quite evenly distributed and they also cover all categories.

Table 52 5G-MOBIX User Story classification (first iteration)

Trial site	Advanced Driving	Vehicles Platooning	Extended Sensors	Remote Driving	Vehicle QoS Support
ES-PT	Complex manoeuvres in cross-border settings • *Scenario 1: Lane merge for automated vehicles* • *Scenario2: Automated Overtaking*		Complex manoeuvres in cross-border settings • *Scenario3: HD maps*	Automated shuttle remote driving across borders • *Scenario 2: Remote Control*	Public transport with HD media services and video surveillance
	Automated shuttle remote driving across borders • *Scenario 1: Cooperative automated operation*		Public transport with HD media services and video surveillance		
GR-TR		Platooning with "see what I see" functionality in cross-border settings	Extended sensors for assisted border-crossing		
			Platooning with "see what I see" functionality in cross-border settings		
DE		eRSU-assisted platooning	EDM-enabled extended sensors with surround view generation		
FI			Extended sensors with redundant Edge processing	Remote driving in a redundant network environment	
FR	Infrastructure-assisted advanced driving				QoS adaptation for Security Check

					in hybrid V2X environment
NL	Cooperative Collision Avoidance		Extended sensors with CPM messages	Remote driving using 5G positioning	
CN	Cloud-assisted advanced driving	Cloud-assisted platooning		Remote driving with data ownership focus	
KR				Remote driving using mmWave communication	Tethering via Vehicle using mmWave communication

In the following table we have refined the classification, and we have assigned a single category to each user story based on its main focus.

Table 53 5G-MOBIX User Story classification considering the main UC category of each User Story

Trial site	Advanced Driving	Vehicles Platooning	Extended Sensors	Remote Driving	Vehicle QoS Support
ES-PT	Complex manoeuvres in cross-border settings			Automated shuttle remote driving across borders	Public transport with HD media services and video surveillance
GR-TK		Platooning with "see what I see" functionality in cross-border settings	Extended sensors for assisted border-crossing		
DE		eRSU-assisted platooning	EDM-enabled extended sensors with surround view generation		
FI			Extended sensors with redundant Edge processing	Remote driving in a redundant network environment	
FR	Infrastructure-assisted advanced driving				QoS adaptation for Security Check

					in hybrid V2X environment
NL	Cooperative Collision Avoidance		Extended sensors with CPM messages	Remote driving using 5G positioning	
CN	Cloud-assisted advanced driving	Cloud-assisted platooning		Remote driving with data ownership focus	
KR				Remote driving using mmWave communication	Tethering via Vehicle using mmWave communication

In the following subsections we are addressing these questions:

- How were the user stories selected?
- To what extent are the user stories unique? Do they have original elements? Are they addressing different cross-border issues or challenges?
- How are the trial sites contributing to the cross-border corridors? Do they have tangible assets that could be transferred to a cross-border corridor?

10.1. Justification for User Stories selection

During the proposal stage, the trial sites designed a set of use cases (now called user stories) that were supported by the added value of 5G connectivity. This initial list was added to the Grant Agreement and included several automated mobility candidates to benefit and even more be enabled by the advanced features and performance of the 5G technologies. For instance, cooperative overtake, highway lane merging, truck platooning, valet parking, urban environment driving, road user detection, vehicle remote control, see through, HD map update or media & entertainment.

From this preliminary list the consortium reformulated its approach to better consolidate the 5G-MOBIX vision. Specifically, four different ingredients were considered as common drivers for all the user stories:

1. Relevance of 5G technologies in AD functions with user stories enabled by core technological innovation from 5G, such as new frequency bands, Cloud Radio Access Network (C-RAN), Mobile Edge Computing and network virtualisation infrastructures.

2. Applicability on cross border context which may include several operator's domains and business models.

3. Use of L4/L5 AD modes at cross border kind of roads, mainly highways.

4. Contribution to the cross-border trial sites.

To double check that the user story ecosystem from 5G-MOBIX is consistent, complementary, solid and relevant the following methodology has been implemented. First a committee was appointed formed by the T2.1 leader (VICOM with use cases at Germany site), the WP2 leader (AALTO with use cases at Finland site), the Technical Coordinator (WINGS with use cases at Greece-Turkey cross border site) and the Project Coordinator (ERTICO).

Each one has performed a peer review with binary (YES/NO) and enumerated lists (trial site and user stories) responses to a set of content and structure related metrics. The goal is to check that all the aspects have been fulfilled and the criteria items are satisfied. Specifically, these seven criteria items have been evaluated:

1. Use Case Category. As agreed by the consortium the use case categories were taken from the document "Enhancement of 3GPP support for V2X scenarios (Release 16)" 3GPP TS 22.186 V16.1.0 (2018-12). Thus, the user stories are forced to be in the scope of one of them.

2. Template compliance. To cover all the different angles from stakeholders with similar structure and details, the consortium follows a template. Firstly, the descriptions identify the target Autonomous Driving functions and the sequence of communications and data exchanged among the actors. Secondly, to show a real impact at cross-border user stories, the different user stories identify a user story from a cross border trial site, underlining how the user story complements the one defined at a cross border trial site with added value from Autonomous Driving functions, 5G technologies or business models. Thirdly, based on the Autonomous Driving features and connectivity challenges, the user stories identify the expected progress beyond the state of the art. Finally, the user stories map requires connectivity features in relation to expected 5G services that the networks will provide.

3. Mapping to a user story present at a cross border. This point includes an explicit and convincing declaration of the contribution of the user story to cross-border corridors. The user story should provide a delta or complementary aspect in terms of 5G technology, AD functions or innovative business models to maximize its impact.

4. Applicability of the user story in a cross-border environment with potential handover and roaming connectivity implications. The dynamics and timeline of the user story must have sense in a cross-border corridor environment potentially including several operator's domains. Thus, the identification of a cross-border trial site with valid environment, in terms of driving situations and 5G features to exercise the user story is essential.

5. Necessity of 5G services and performance. The 5G network must be a catalyser of the CCAM use case enabling the user story, not just providing an enhanced performance from LTE.

6. L4/L5 Autonomous Driving functions are the main user story enabler. The user story must pivot around L4/L5 AD functions with a clear scope in improving driving or safety.

7. Overlap with another user story claiming similar contribution. Different trial sites can target the same use case category (e.g. remote driving) but each implementation needs to add some differential value.

Once the first review of all those aspects were done by all the members of the committee, the results were reported to user story leaders and trial site leaders to invite them to fix all the aspects. This report is a table that includes the vision of all the reviewers for all the evaluated aspects. Looking like a dashboard, green and red colours point out the satisfied or insufficient aspects. This table was produced and shared online to ease a live update of any aspect by the reviewers and an instant awareness of the current status by the user story and trial site leaders. To ease this user story update or reshape, specific comments were done by the Technical Coordinator in each of the documents describing user stories. Figure 32 depicts the review work flow.

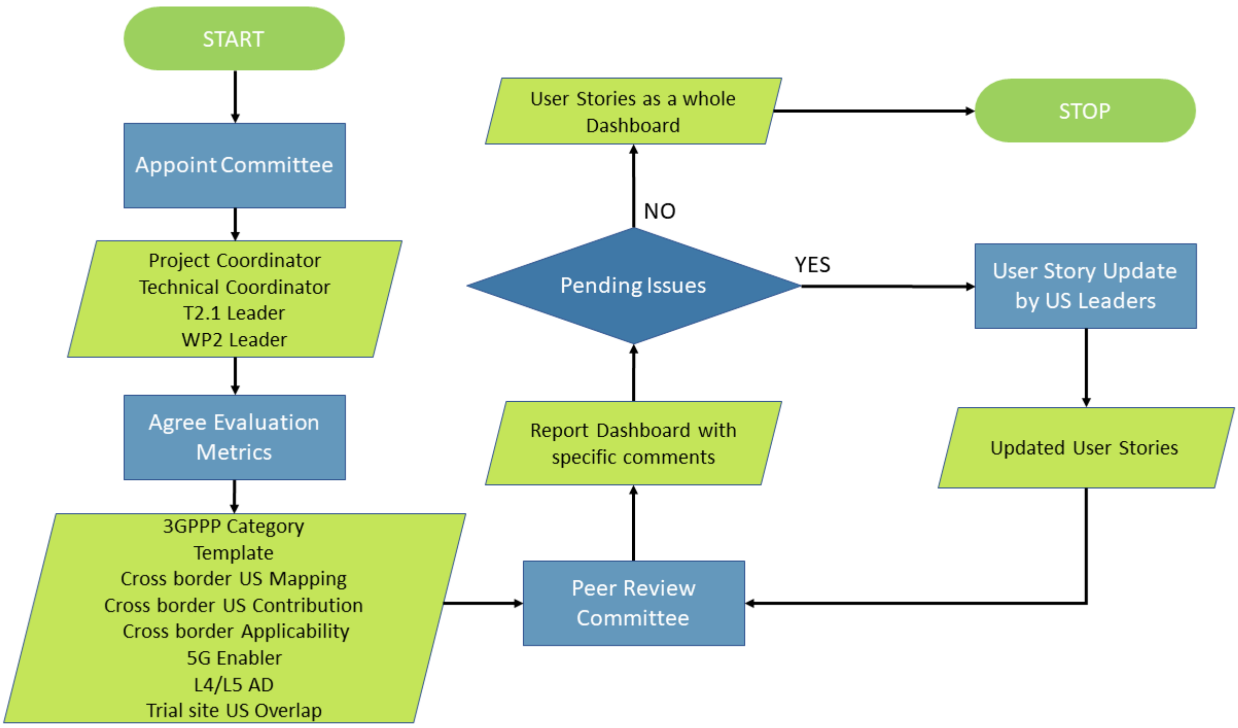

Figure 32 User Story review workflow.

The first version of the user stories was presented in the first version of this deliverable, v1.0, that was submitted on April 30, 2019. Due to the comments received during the interim review and the comments of the Review Report we have reformulated our approach presentation with the following high-level change: now use cases are called user stories and are described under each use case category. Some of the user stories have also been refined for a better alignment with EC's vision of 5G corridors.

10.2. Identification of uniqueness, complementarity and challenges of User Stories

The objective of the H2020-ICT-2018-20 call is to qualify 5G as a core connectivity infrastructure for the support of CCAM in cross border scenarios. Consequently, the duplication of development effort in the trial sites must be minimised as much as possible as the focus is on getting insights from the trials. 5G-MOBIX use cases and user stories have been designed accordingly. However, in order to check that this design requisite has been fulfilled, a formal procedure was started to identify the unique components of the user stories in a systematic and objective way. The WP2 leader AALTO and T2.1 leader VICOM performed one-on-one meetings with trial site leaders compiling data that express the uniqueness of the planned activities around a user story in a trial site. For this purpose, a table was used that contained the following fields to be completed:

- Use Case Category. As agreed by the consortium the use case categories were taken from the document "Enhancement of 3GPP support for V2X scenarios (Release 16)" 3GPP TS 22.186 V16.1.0 (2018-12). This classification has already been described in Section 2. Thus, the user stories are forced to be in the scope of one of them.
- Number of actors. The deployment setup including the participation of different key actors in the tests of the use case in the user story. The actors would be:
  - Antennas. PLMN (gNB+eNB) which transmits data from CCAM services tested.
  - OBU. Attached to connected vehicles.
  - RSU. Present in the tests along the vehicles route.
  - MEC. Processing or traffic boosting infrastructures exploited by the CCAM service.
  - Cloud. The CCAM service connects to remote cloud services thorough the Internet or the script is managed locally without requiring the connection to any remote service.
  - Remote Operations Centre (ROC). An infrastructure connected to the evaluation setup is monitoring and controlling the CCAM service.
  - Road sensors. Present in the tests along the vehicles route such as CCTV cameras or a radar.
- Processing location. The demanding processing capacity required to process all the data from the sensors and the service in real time follow different models, and different parts of it can be assigned to a processing infrastructure to better fit into data latency, privacy, autonomy and visibility. This way the main infrastructures which will process data will be:
  - Vehicle. The data is processed onboard in the computing resources equipped at the vehicle. This is mainly used by onboard ADAS algorithms.
  - MEC. The MEC service embedded at the RAN can provide a variety of low-latency services such as, gateway different radio technologies, re-stream sensor flows, data fusion, data cache, decision making, discovery, etc.
  - Cloud. Acting as a primary part of a CCAM service cloud services can perform advanced tasks requiring synchronization of big volumes of distributed data or high-performance computing for non-time sensitive CCAM services.

- V2X communications model. The interlocutors on the CCAM service driven by the present actors and their required interaction result in V2N, V2I, V2V and V2P communications.
- Vehicles abilities. The participants in the evaluation setups can ship AD functions L4/5, AD functions L1/2/3, Internet connection or without connectivity.
- 5G features. The different skills than can be ready at the evaluation setups include 5G Core, Network Slicing and 5G-based positioning.
- Cross-border issues. The list with the target cross-border issues to be met in the implementation of a use case tested in a user story.

In addition to this, the issues or technical challenges addressed by each user story were identified.

A set of figures to underline the unique components brought by each site to each use case category are depicted below. The data used to create these figures can be found in Annex 1.

10.2.1. Advanced Driving category

This radar chart graph underlines the utilization of several items in the French evaluation scenario, not present at the others such as the road sensors and the edge systems for manoeuvre assistance. The evaluation scenario from the Netherlands brings the V2V communications and CPM messaging to synchronise driving manoeuvres. While the Chinese one adds the cloud infrastructure as the main driver for the advanced driving service. The complete table used to create this graph can be found in Annex 1.

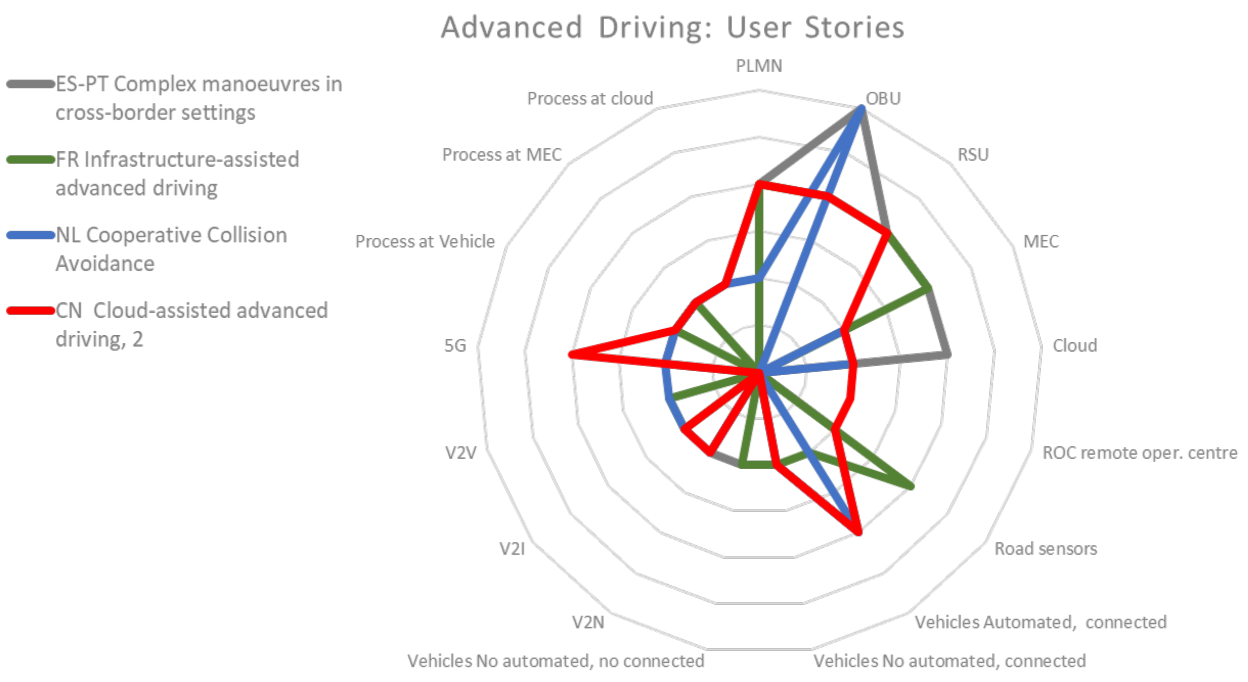

Figure 33 Differences on User Story items of Advanced Driving category (UCC 1).

This unique proposition becomes more evident in the next diagram where most relevant road and communication actors takes place, where grey is employed for Spanish-Portugal cross-border corridor, blue is employed for the Netherlands, green for France and red for China.

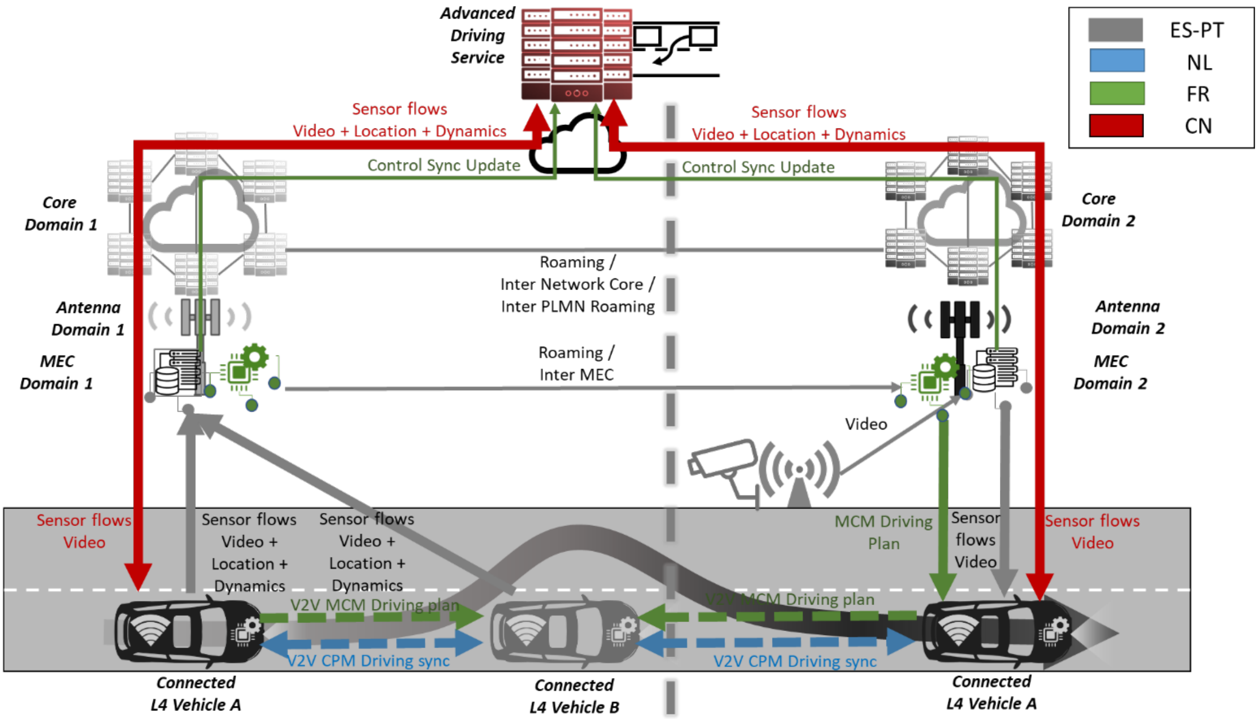

Figure 34 Differences on User Stories of Advanced Driving.

There are also differences in the cross-border issues addressed by the user stories as it is depicted on Table 9 from Section 5. For instance, ES-PT is the only one addressing NSA Roaming Latency, Continuity Protocol and Federation Trust. FR is the only one addressing Hybrid Handover Latency, Geo Networking Overhead, Real-time multi-tier processing and data privacy. NL is the only one addressing SA Roaming Latency, Performance Continuity, Sensor Compliance and Neutrality Regulation. Finally, China is the only one addressing Data Ownership.

10.2.2. Vehicles Platooning category

This graph underlines the utilization of several items in the German evaluation scenario, not present at the others such as the road sensors, the RSUs and the cloud infrastructure orchestrating the platooning service. The evaluation scenario from China brings the data ownership and privacy protection techniques. The complete table used to create this graph can be found in Annex 1.

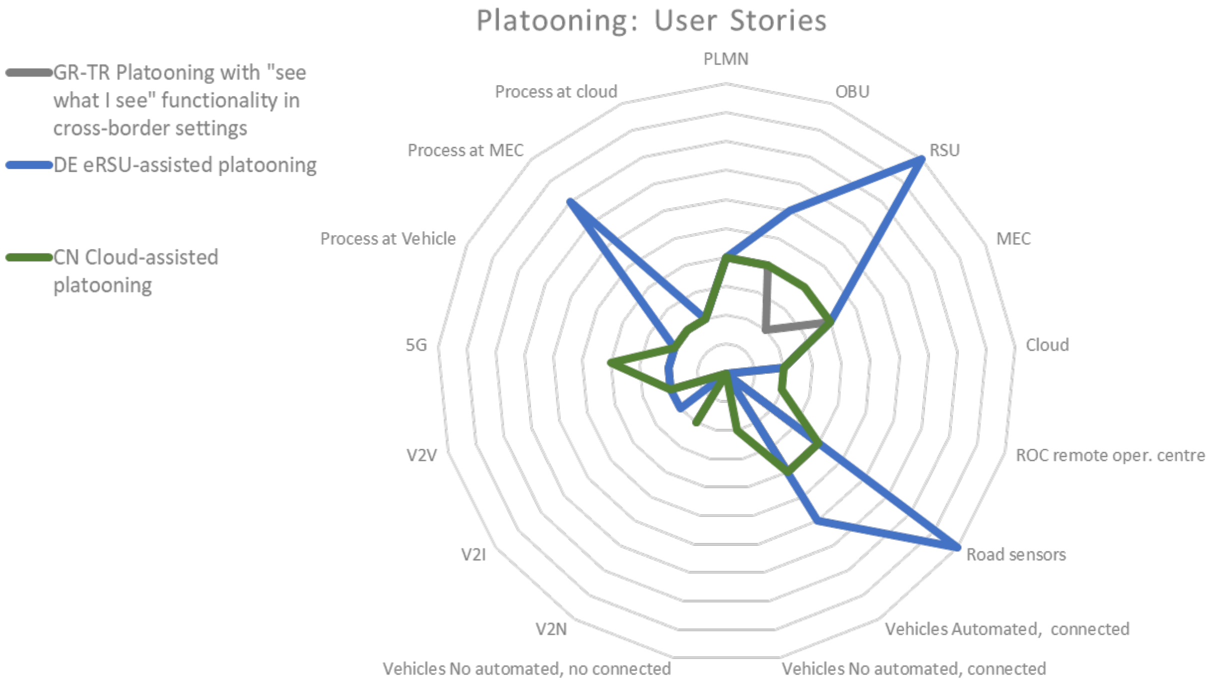

Figure 35 Differences on User Story items of Platooning category (UCC2).

This unique proposition becomes more evident in the next diagram where most relevant road and communication actors takes place, where grey is employed for Greece-Turkey cross-border corridor, blue is employed for Germany and green for the Chinese one.

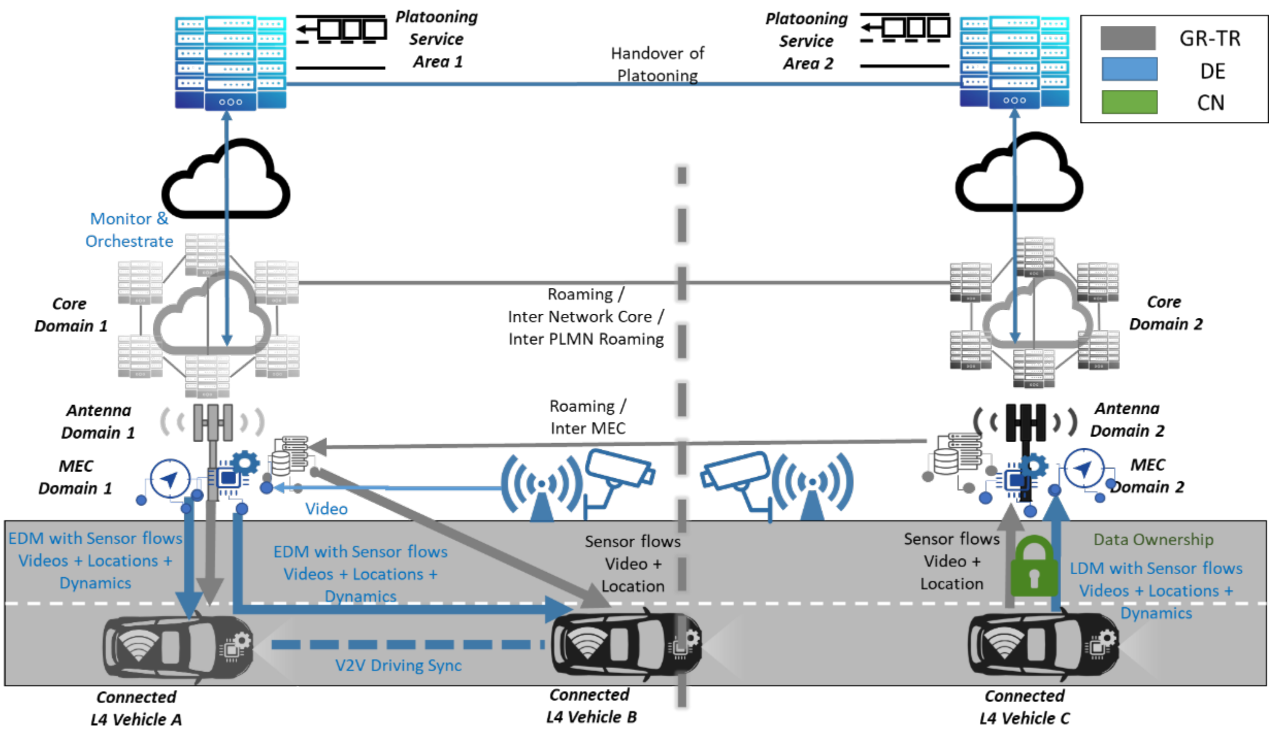

Figure 36 Differences on User Stories of Platooning.

There are also differences in the cross-border issues addressed by the user stories as it is depicted on Table 18 from Section 6. For instance, GR-TR is the only one addressing Accurate Geo-Positioning, Anonym Privacy and Law enforcement interaction. DE is the only one addressing Hybrid Networking, Dynamic QoS Continuity, Discovery Trust and Sensor Compliance. And CN is the only one addressing Data Ownership.

10.2.3. Extended Sensors category

This graph underlines the utilization of several items in the German evaluation scenario, not present at the others such as the road sensors, the RSUs and the demanding MEC processing of LDMs and EDMs, the adaptation of data resolutions and the ROI application to the discovery service supporting the extended sensors application to share sensor flows via V2V communications. The evaluation scenario from Finland brings MEC redundancy, balancing and handover techniques. The Dutch evaluation scenario will exploit mm-wave sensors to enable accurate location. The complete table used to create this graph can be found in Annex 1.

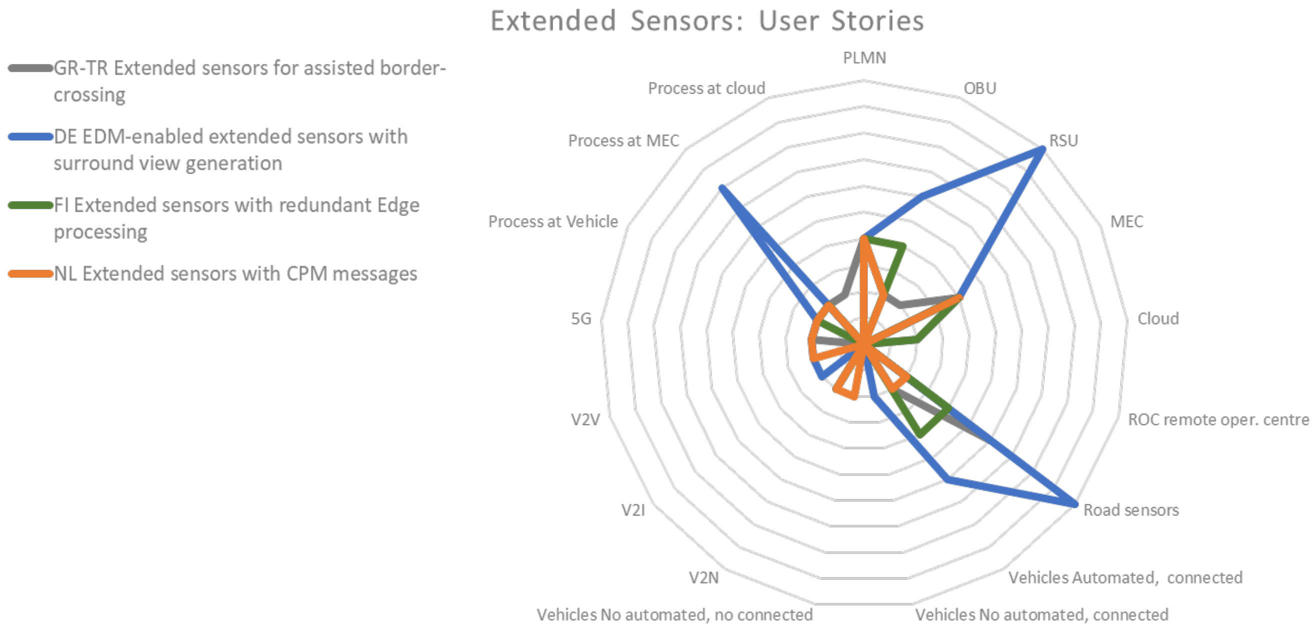

Figure 37 Differences on User Stories items of Extended Sensors category (UCC3).

This unique proposition becomes more evident in the next diagram where most relevant road and communication actors takes place, where grey is employed for Greece-Turkey cross-border corridor, blue is employed for Germany, green for Finland and orange for the Dutch one.

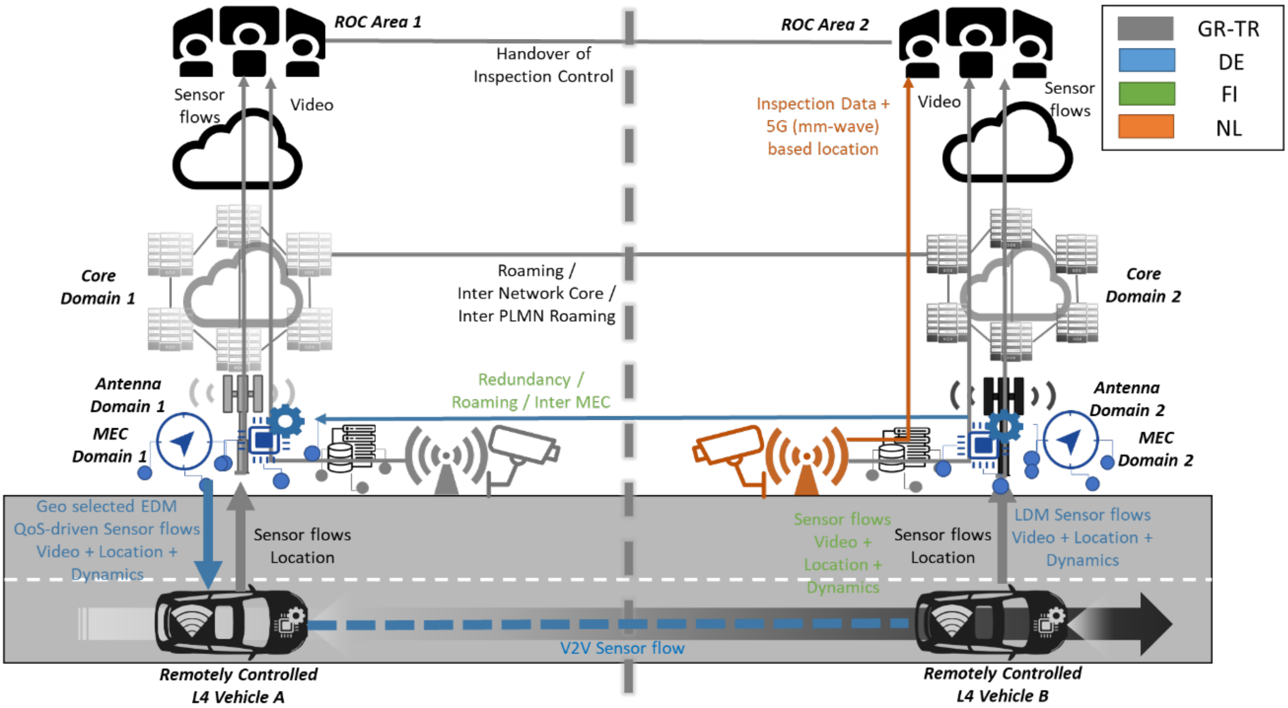

Figure 38 Differences on User Stories of Extended Sensors.

There are also differences in the cross-border issues addressed by the user stories as it is depicted on Table 27 from Section 7. For instance, GR-TR is the only one addressing Low coverage Handover, Continuity Protocol, Real-time Multi-tier Processing, Autonomous Vehicle regulation Compliance and Geo-dependant spectrum. DE is the only one addressing Service & device isolation, Data Interoperability, Geo-driven Discovery and Data Privacy. FI is the only one addressing APIs Interoperability, On-demand Processing and Discovery Trust. NL is the only one addressing SA Roaming Latency, V2X Continuity and Neutrality regulation.

10.2.4. Remote Driving category

This graph underlines the utilization of several items in the Dutch evaluation scenario, not present at the others such as the slicing techniques at the 5G network core and the mm-wave sensors to provide accurate location to the remote driving service. The evaluation scenario from Finland brings network redundancy and bonding techniques. The Chinese evaluation scenario focuses on data ownership and privacy protection techniques. Finally, Korean one ships mm-wave RSU communications. The complete table used to create this graph can be found in Annex 1.

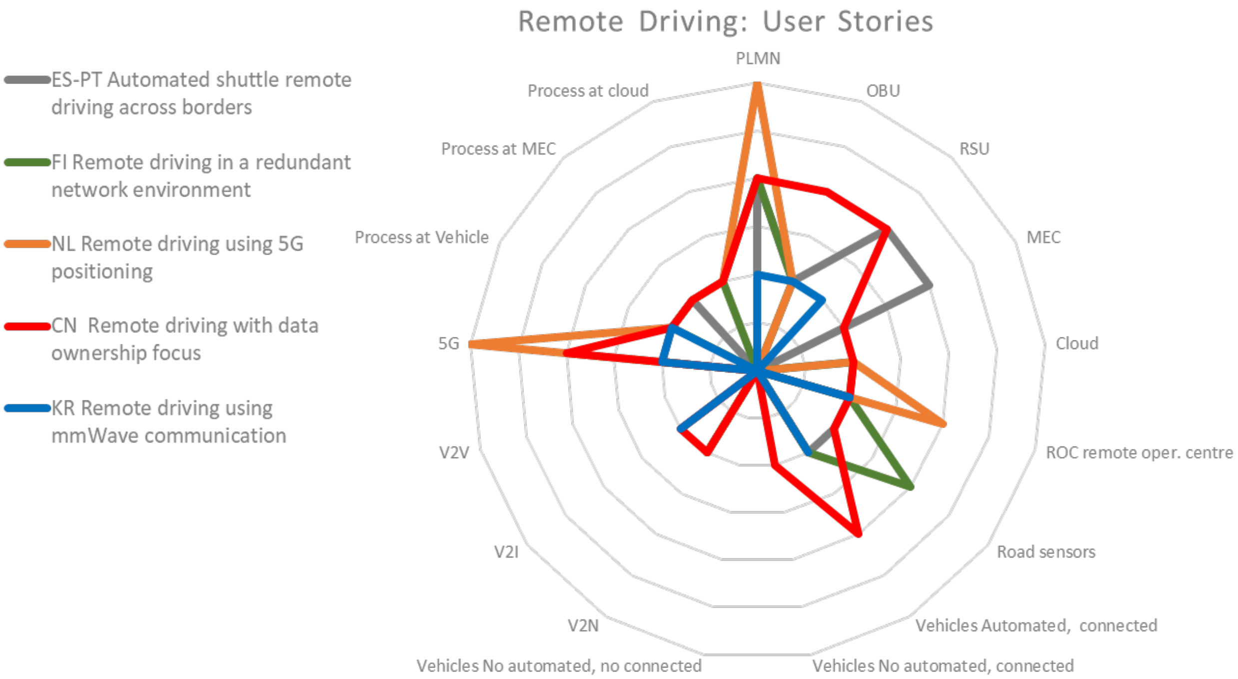

Figure 39 Differences on User Stories items of Remote Driving category (UCC4).

This unique proposition becomes more evident in the next diagram where most relevant road and communication actors takes place, where grey is employed for Spanish-Portugal cross-border corridor, orange is employed for the Netherlands, green for Finland and red for China and blue for the Korean one.

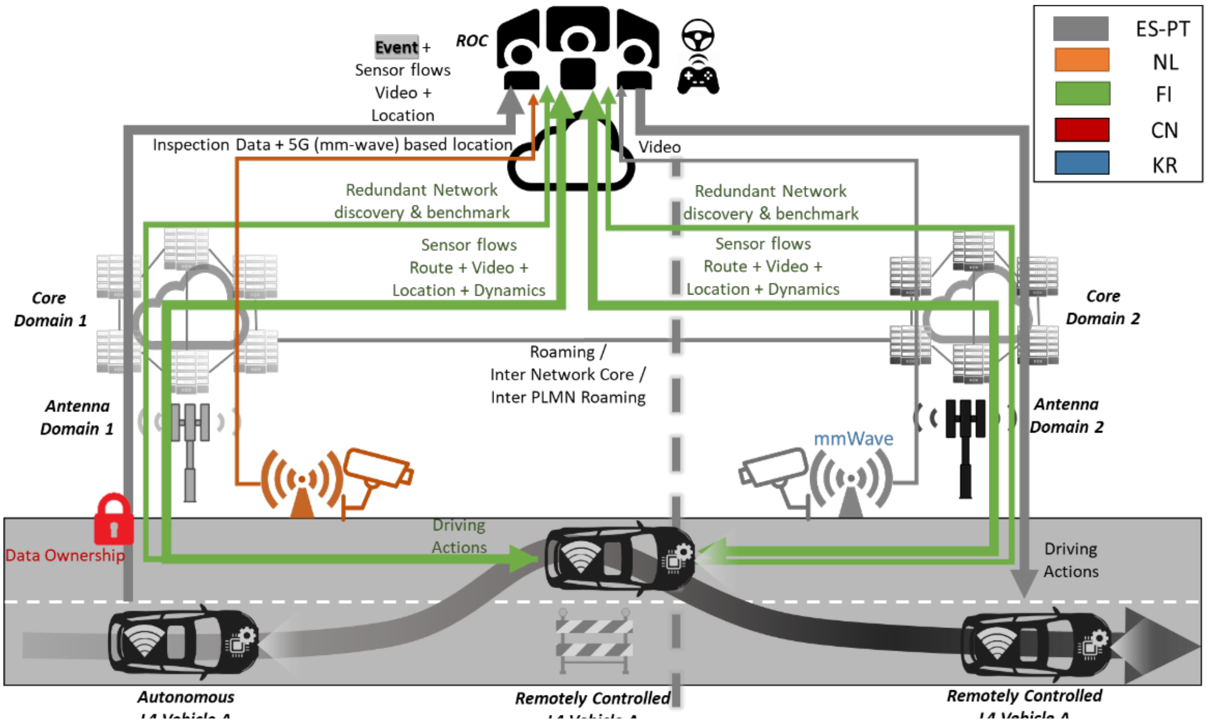

Figure 40 Differences on User Stories of Remote Driving.

There are also differences in the cross-border issues addressed by the user stories as it is depicted on Table 34 from Section 8. ES-PT is the only one addressing Continuity Protocol, Real-time Multi-tier Processing, Autonomous Vehicle regulation Compliance and Autonomous Vehicle regulation Compliance. NL is the only one addressing SA Roaming Latency and Performance Continuity. CN is the only one addressing Data Ownership.

10.2.5. Vehicle QoS Support category

This graph underlines the utilization of several items in the French evaluation scenario, not present at the others such as the satellite communications and the MEC processing for adaptation of data formats to support the remote surveillance service. The evaluation scenario from Korea brings V2V communications and mm/wave communications to provide high bandwidths to surrounding users turning vehicles into moving hotspots. The complete table used to create this graph can be found in Annex 1.

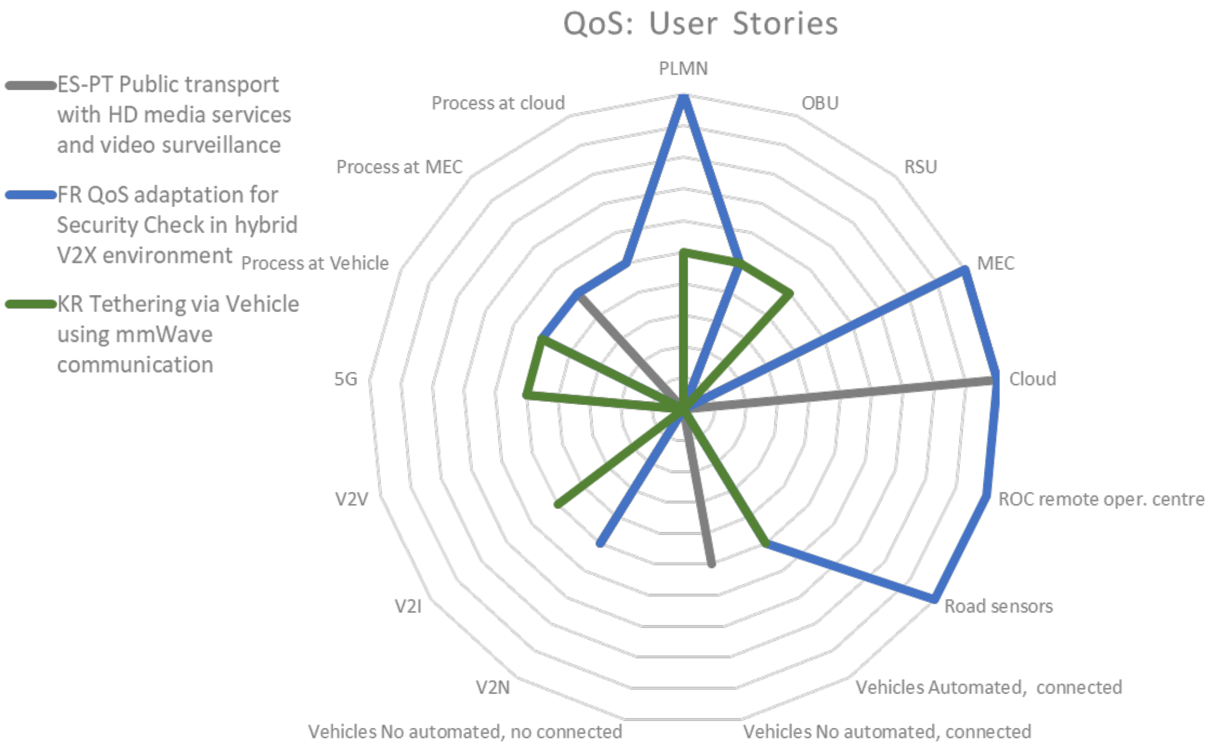

Figure 41 Differences on User Stories items of Vehicle QoS support category (UCC5).

This unique proposition becomes more evident in the next diagram where most relevant road and communication actors takes place, where grey is employed for Spanish-Portugal cross-border corridor, blue is employed for France and green for the Korean one.

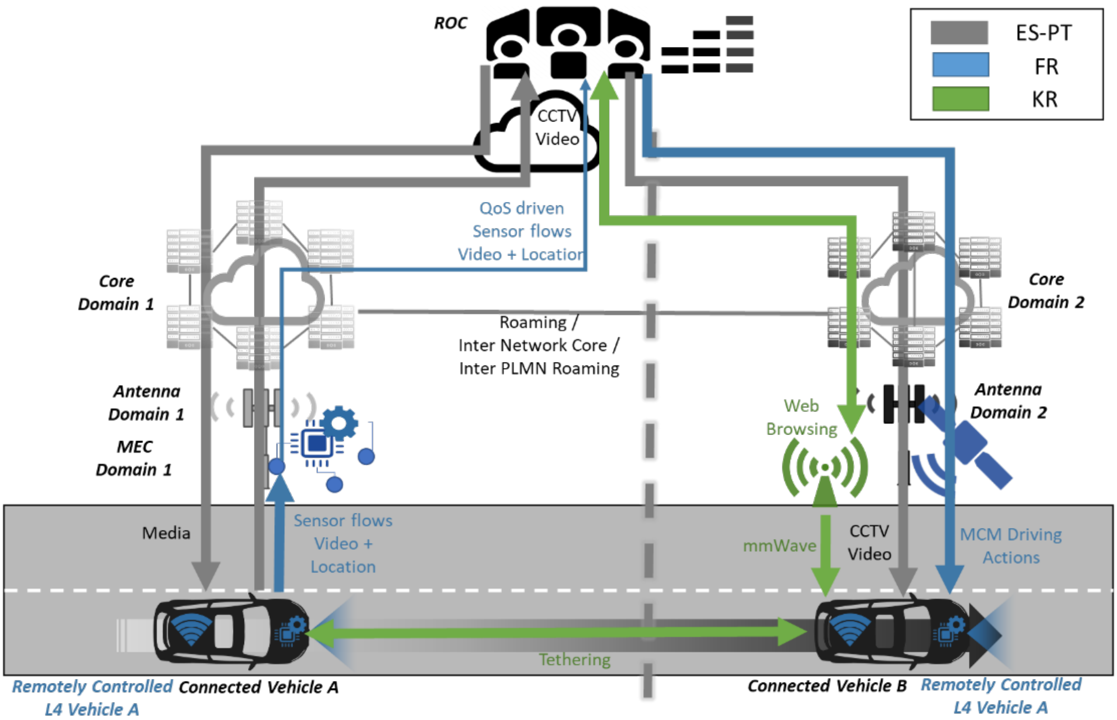

Figure 42 Differences on User Stories of Vehicle QoS support.

There are also differences in the cross-border issues addressed by the user stories as it is depicted on Table 45 from Section 9. ES-PT is the only one addressing NSA Roaming Latency, Continuity Protocol and On-demand Processing. FR is the only one addressing Hybrid Networking, Dynamic QoS Continuity, Data Privacy, Data Ownership and Law enforcement interaction. The issues addressed by KR are also addressed by FR, but the user story approach is very different.

10.3. Overview of transferable assets from local sites to CBCs

According to the Grant Agreement, the main objective of D2.1 is to detail the 5G-MOBIX use cases. In the current version of D2.1 we have gone some steps further defining a portfolio of tangible assets that could be transferred to the cross-border corridors from the local trial sites. This portfolio of tangible assets is defined for each user story planned to be implemented at a local trial site. The local user stories have therefore included a description of how they plan to contribute to the cross- border sites beyond insights, complementarity, knowledge exchange or possible consultancy. The assets are heterogeneous and cover many aspects that are not yet covered by the 5G-MOBIX cross-border corridors. Some of them are focused on communication aspects and others on AD functionalities. Others offer hardware pieces or equipment. In all cases, they are key enabling components for CCAM that can enhance the current demonstrations planned at cross-border sites.

The list of transferable assets will be refined and presented with much more detail in forthcoming WP3 and WP4 deliverables. The list presented here in Sections 5-9 only serves to kick off the interaction between local sites and cross-border corridors. The scope of WP3 (Development, integration and roll-out) and WP4 (Trials) is more appropriate for a detailed discussion of development, deployment and execution.

11. CONCLUSIONS

Europe set ambitious objectives for 5G deployment in the 5G Action Plan from 2016 as well as for pan-European 5G Corridors for Connected and Automated Mobility (CAM) in the 3rd Mobility Package from 2018. This year, on February 7, the European Commission held a workshop with all stakeholders interested in the deployment of 5G networks along roads to kick off the definition of a European 5G Strategic Deployment Agenda (SDA) for Connected and Automated Mobility. 5G-MOBIX is fuelled by all these initiatives and committed to deploy and test use cases that will contribute to the success of these initiatives.

This document presents the resulting 5G-MOBIX use cases after a throughout review of the use cases included in the proposal. The use cases were rearranged and refined to be completely aligned with European Commission's vision of 5G cross-border corridors. The Spain-Portugal corridor connecting Vigo and Porto, and the Greece-Turkey corridor located in the South-Eastern borders of Europe are the two-flagship cross-border corridors of 5G-MOBIX. In addition, there are six trial sites located inland in France, Germany, Netherlands, Finland, China and South Korea.

The work planned at the local sites contribute to the 5G cross-border corridor roadmap in diverse aspects and complement the set of use cases, now called user stories, to be deployed in 5G-MOBIX cross-border corridors. In some cases, they target a common situation in cross-border corridors that is not fully covered in the 5G-MOBIX cross-border user stories. In other cases, they plan a different implementation of a cross-border user story which is also interesting to test from the business or technological point of view. Sometimes, the implementation of a user story variant is simply not feasible in a real cross-border corridor and needs to be implemented in a more controlled environment present at a local site. And in general, testing different implementations of the same use case category (e.g. remote driving) in different driving environments is very valuable.

It is also important to highlight the participation of two non-European countries, China and South Korea, that enrich the consortium and further enhance the alignment of views on 5G. Options for jointly drafting white papers and positions about cross-border corridor use cases resulting from 5G-MOBIX are envisaged. Their unique focus on data ownership and mmWave communications is also very valuable and the obtained insights will feed the European partners.

To sum up, this document describes the planned 5G-MOBIX user stories which are classified into five categories (Advanced Driving, Vehicles Platooning, Extended Sensors, Remote Driving and Vehicle QoS Support) and distributed among eight trial sites. All of them are designed to be meaningful in a cross-border corridor context and aim to contribute to Europe's ambition to lead in large-scale testing and early deployment of 5G infrastructure, enabling connected and automated mobility.

12. ANNEX 1: OVERVIEW OF UCC COMPONENTS

This annex contains a table per use case category that depicts the main components of the user stories under that category.

12.1. Advanced Driving UC Category overview

	Actors (number)							Processing, what and where?				V2X				Vehicles in use			5G functionalities		
Site	**PLMN**	**OBU**	**RSU**	**MEC**	**Cloud**	**ROC remote oper. centre**	**Road sensors**	**Vehicle**	**MEC**	**Cloud**	**Other, e.g. desktop app**	**V2N**	**V2I**	**V2V**	**V2P**	**Automated, connected**	**No automated, connected**	**No automated, no connected**	**(5G) core**	**Slicing**	**5G-based positioning**
ES-PT	2	3	2	2	2	-	radar	ADAS	gateway	HD mapping	-	Y	-	-	-	2	1	1	Core ES (Telefónica): ph1 NSA, ph2 SA Core PT (NOS): ph1 NSA, ph2 SA	Just in SA	-
FR	2	2	2	2	-	-	lidars, cameras	ADAS	perception, data fusion, trajectory guidance	-	-	-	Y	Y	-	1	1	1+	-	-	-
NL	1	3	-	1	1	-	-	2 x ADAS / L4	data ingestion, primary/secondary decision making & automated breaking	data ingestion, primary/secondary decision making & automated breaking		Y	Y	Y	-	2	1	-	distributed	TBD	-
CN	2	2+	2	1	1	1	cameras	ADAS	information fusion and sharing,decision support	HD Video storage and analysis,HD mapping	-	Y	Y	-	-	2	1	-	-	eMBB +uRLLC	-

Figure 43 Advanced Driving UC Category overview

12.2. Vehicles Platooning UC Category overview

	Actors (number)							Processing, what and where?				V2X				Vehicles in use			5G functionalities		
Site	PLMN	OBU	RSU	MEC	Cloud	ROC remote oper. centre	Road sensors	Vehicle	MEC	Cloud	Other, e.g. desktop app	V2N	V2I	V2V	V2P	Automated, connected	No automated, connected	No automated, no connected	(5G) core	Slicing	5G-based positioning
GR-TR	2	2	1	2*	1	-	lidars, cameras	ADAS, 4K video compression, encoding	streaming	streaming	-	Y	-	Y	-	2	-	-	distributed	-	-
DE	2	3	10	2	1	-	Object detection sensros, traffic analysis sensors, environmental sensors , weather sensors, intelligent light sensors	ADAS	data fusion and sharing, LDM/EDM generation	Management & Orchestration	-	-	Y	Y	-	3	-	-	2 cores: TUB Core and DT core	TBD. Possible with the TUB core	-
CN	2	2+	2	2	1	1	lidars, cameras	ADAS	data fusion and sharing	vehicle monitoring,HD mapping	-	Y	-	Y	-	2	1	-	-	-	-

Figure 44 Vehicles Platooning UC Category overview

12.3. Extended Sensors UC Category overview

	Actors (number)							Processing, what and where?				V2X				Vehicles in use			5G functionalities		
Site	PLMN	OBU	RSU	MEC	Cloud	ROC remote oper. centre	Road sensors	Vehicle	MEC	Cloud	Other, e.g. desktop app	V2N	V2I	V2V	V2P	Automated, connected	No automated, connected	No automated, no connected	(5G) core	Slicing	5G-based positioning
GR-TR	2	1	1	2*	1	-	cameras, radar, environmental	ADAS	data ingestion, decision making, automated breaking	data ingestion, decision making, automated breaking	-	Y	-	-	Y	1	-	-	distributed	-	-
DE	2	3	10	2	0	-	Object detection sensros, traffic	ADAS	data fusion and sharing, LDM/EDM generation	-	-	-	Y	Y	-	3	1	-	2 cores: TUB Core and DT core	TBD. Possible with the TUB core	-
FI	2	2	-	2	1	-	radar, video	ADAS	data fusion, caching	data fusion (for evaluation against MEC)	-	Y	-	-	-	2	-	-	-	-	-
NL	2	Y	?	2			Y	ADAS / L4	data collection and redistribution			Y		Y (PC5 ambition)		1	>1	1	SA & NSA	Y	

Figure 45 Extended Sensors UC Category overview

12.4. Remote Driving UC Category overview

	Actors (number)							Processing, what and where?				V2X				Vehicles in use			5G functionalities		
Site	PLMN	OBU	RSU	MEC	Cloud	ROC remote oper. centre	Road sensors	Vehicle	MEC	Cloud	Other, e.g. desktop app	V2N	V2I	V2V	V2P	Automated, connected	No automated, connected	No automated, no connected	(5G) core	Slicing	5G-based positioning
ES-PT	2	1	2	2	-	1	Road user detector	ADAS	gateway	-	remote operation (desktop app)	Y	-	-	-	1	-	-	Core ES (Telefónica): ph1 NSA, ph2 SA Core PT (NOS): ph1 NSA, ph2 SA	Just in SA	Yes
FI	2	1	-	-	1	1 to 2	radar, video	ADAS	-	streaming	remote operation (desktop app)	Y	-	-	-	1	-	-	-	-	-
NL	3	1	-	-	1	2	-	ADAS / L4	2	streaming	remote operation (desktop app) & virtual remote operatoin	Y	-	-	-	1	-	-	-	-	1
CN	2	2+	2	1	1	1	cameras	ADAS	information fusion and sharing,decision support	HD Video storage and analysis,HD mapping	-	Y	Y	-	-	2	1	-	-	-	-
KR	1	1	1	-	-	1	-	ADAS	'	-	remote operation (desktop app)	-	Y	-	-	1	-	-	Y	Y	-

Figure 46 Remote Driving UC Category overview

12.5. Vehicle QoS Support UC Category overview

	Actors (number)							Processing, what and where?				V2X				Vehicles in use			5G functionalities		
Site	PLMN	OBU	RSU	MEC	Cloud	ROC remote oper. centre	Road sensors	Vehicle	MEC	Cloud	Other, e.g. desktop app	V2N	V2I	V2V	V2P	Automated, connected	No automated, connected	No automated, no connected	(5G) core	Slicing	5G-based positioning
ES-PT	2	1	-	2	2	-	'	-	gateway	vehicle monitoring and surveillance	-	Y	-	-	-	-	1	-	Core ES (Telefónica): ph1 NSA, ph2 SA Core PT (NOS): ph1 NSA, ph2 SA	Just in SA	-
FR	2	1	-	2	2	2	lidars, cameras	ADAS	perception assistance, tx CPMs	perception, data fusion	adaptively/ redundant network… , satellite	y	-	-	Y	1	-	-	-	-	-
KR	1	1	1	-	-	-	-	ADAS	'	-	-	-	Y	-	-	1	-	-	Y	Y	-

Figure 47 Vehicle QoS Support UC Category overview

13. ANNEX 2: LOCATION OF LOCAL TRIAL SITES

13.1. German (DE) Trial Site

Table 54 German location overview

Trial site class	Local site
Country	Germany
City	Berlin & Stuttgart

Germany has one trial site located in Berlin. The Berlin corridor builds on the national flagship project Diginet-PS (www.diginet-ps.de) and comprises the full dynamics of a dense urban environment. The tests and trials of the project's use cases are conducted in a fully dynamic dense urban setting. The Berlin corridor is situated in the centre of Berlin, Straße des 17. Juni and is a 4km long road extending from Ernst-Reuter-Platz to Brandenburger Gate. The corridor is open and urban with three lanes in each direction, two complex roundabouts (with 5 roads and multiple lanes), and a high traffic intensity during working hours. The corridor is equipped with a number of different types of sensors including traffic analysis, object detection, queue detection, parking, road-condition, environment, intelligent light. The sensors are connected to the extended roadside units, which are equipped with compute infrastructure, machine learning toolboxes, and communication infrastructure. The central cloud / data-centre is equipped with GPUs and Hyperflex compute infrastructure using industry grade aggregation software. The transport network is SDN enabled. The traffic light control systems with group control for vehicles, bicycles, pedestrians, and handicapped citizens, are equipped with communication infrastructure. The trial site presents complex parking situations including marked, non-marked, parallel, slanted, centre island, and separate parking areas. Currently, 4G and DSRC communication is used on the trial sites, for 5G-MOBIX, 5G network infrastructure (from Deutsche Telecom) is planned.

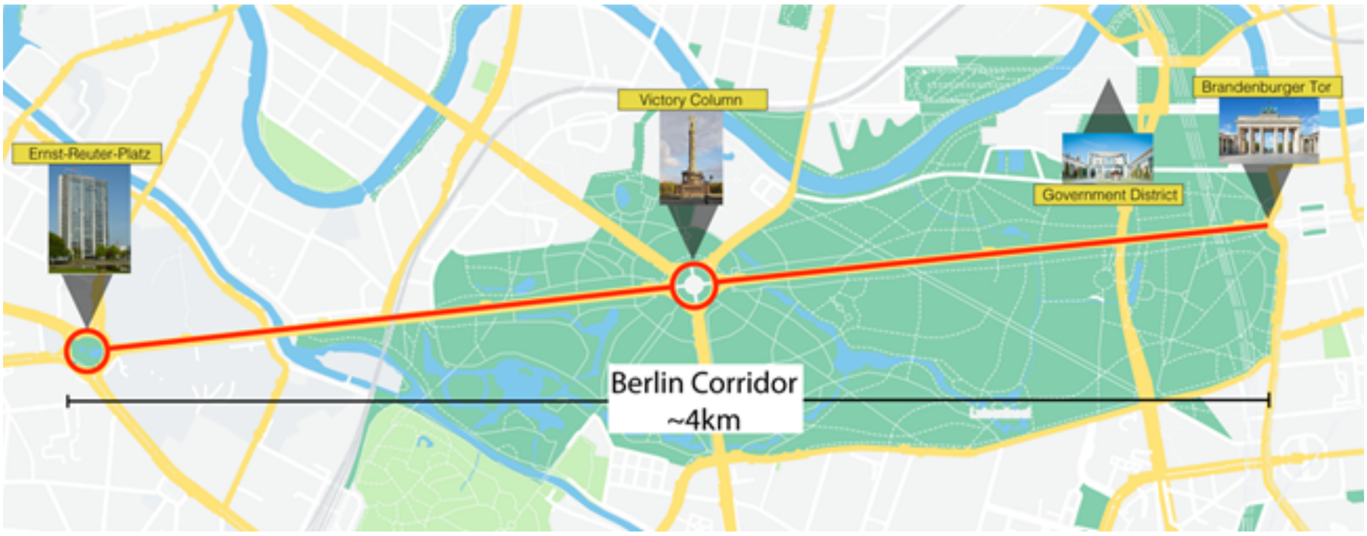

Figure 48 German (DE) trial site

13.2. Finnish (FI) Trial Site

Table 55 Finnish location overview

Trial site class	Pre-deployment
Country/Countries	Finland
City/Cities	Espoo

The Finland (Espoo) pre-deployment trial site is located within and around the Otaniemi area of Aalto University. The 5G-MOBIX testbed will build on a legacy of 4G/5G testbeds deployed in the Otaniemi area in past/ongoing national projects. The first of these national projects is the TAKE-5 project (years 2015-2018), which deployed a 4G/5G testbed as part of the planned national 5G Test Network Finland (5GTNF)[6]. The successor of the TAKE-5 project is the national project 5G-FORCE, which from early 2019 will to continue to enhance the Otaniemi testbed as part of an integrated national testbed. This Otaniemi testbed is targeted for testing, piloting and validating a multitude of 5G use cases including smart factories, smart grids and automotive (the latter being relevant for 5G-MOBIX). In summary, 5G-MOBIX anticipates the following value add from the 5G-FORCE project:

- 5G-MOBIX avoids duplication of deploying infrastructure by leveraging as much as possible radio, edge and core network infrastructure deployment by 5G-FORCE;
- 5G-MOBIX utilising additional technical support from 5G-FORCE in terms network configuration, upgrades, fault management etc.;

[6] http://5gtnf.fi/projects/take-5/

- 5G-MOBIX obtains channel for collaboration with vendors (e.g. Nokia, Ericsson) and operators within the 5G-FORCE consortium.

Figure 49 The FINLAND pre-deployment trial site

13.3. French (FR) Trial Site

Table 56 French location overview

Trial site class	Local site
Country/Countries	France
City/Cities	Satory & Linas-Montlhéry

VEDECOM is going to use two trial sites located in the suburb of Paris: Satory and the UTAC CERAM. These are closed test sites composed of 12 Km of different type of roads (highway, urban, rural, parking and braking circuits) and associated facilities. 5G equipment is being installed in the course of 2019 and will be available for 5G-MOBIX.

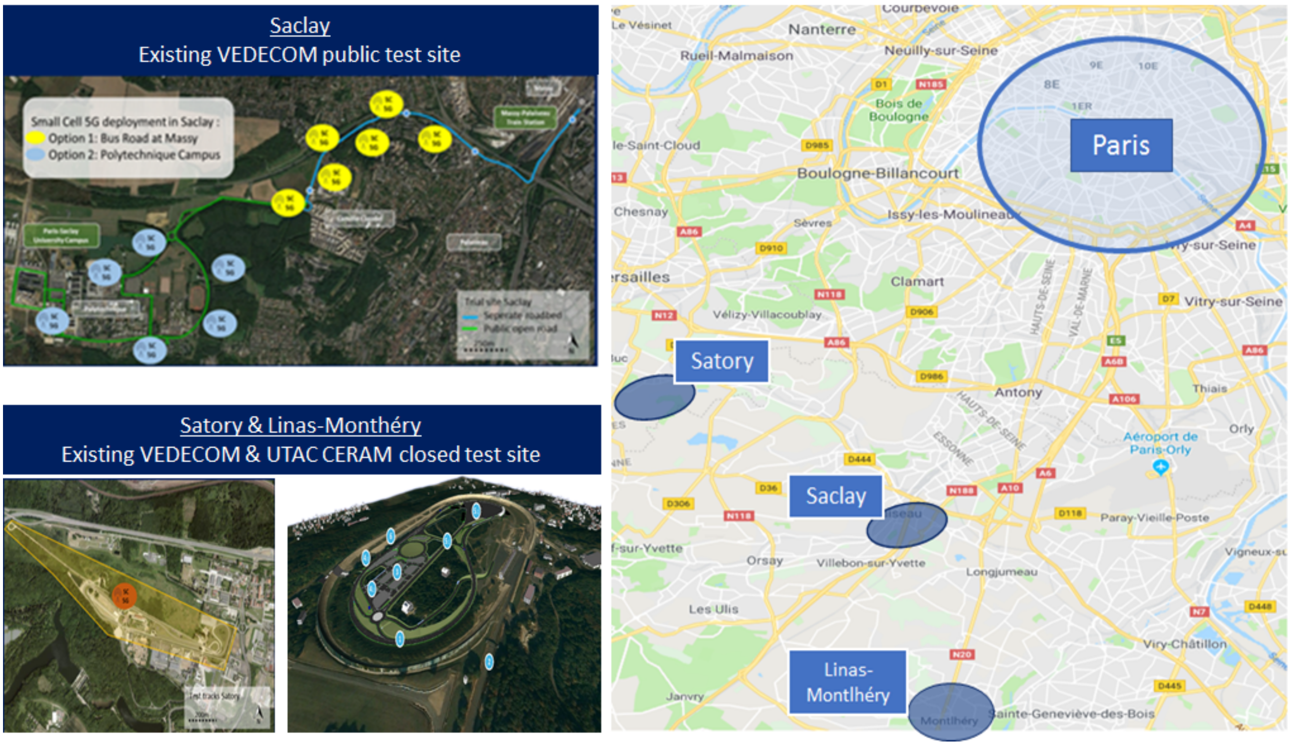

Figure 50 French trial sites

The closed site of Satory is composed of closed roads (private test tracks). The second closed site of UTAC CERAM autodrome is situated at Linas-Montlhéry.

As illustrated by the figure below, the trial site at Linas-Monthéry provides a variety of road configurations and presents a complete road infrastructure circuit to efficiently test the proposed use cases: from highways with three lane, 2.2 Km of length and high permitted velocity to urban circuit with traffic lights and parking area.

For the telecommunication side, the circuit is being equipped with 5G network infrastructure. This latter will be available by September 2019 and provided by both Orange and Bouygues Telecom operators. This will allow us to test roaming operations during use cases. Moreover, the site is already equipped with C-V2X RSUs, located at each 200m of the highway circuit.

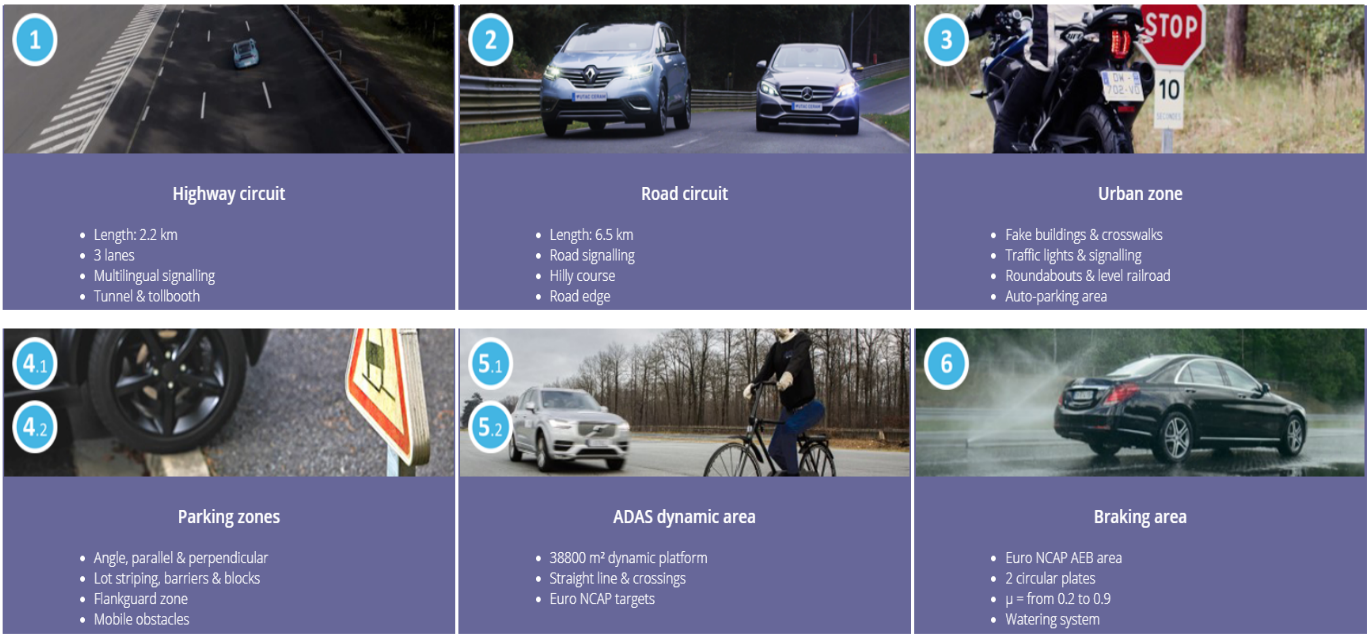

Figure 51 Road infrastructures and facilities provided by UTAC CERAM test site

13.4. Dutch (NL) Trial Site

Table 57 Dutch location overview

Trial site class	Corridor / Local site
Country/Countries	The Netherlands
City/Cities	Eindhoven, Helmond

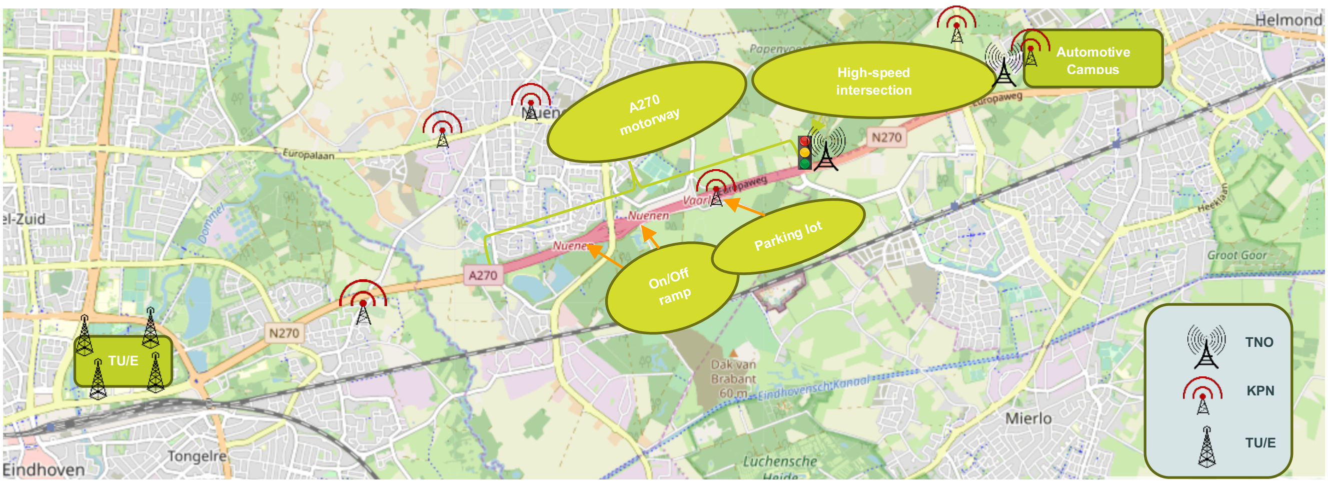

Figure 52 NL trial site

The NL trial considered is located at the motorway A270/N270 connecting the cities of Eindhoven and Helmond in the Netherlands which has road exemptions to support automated driving in mixed traffic conditions. Trials start at Technical University of Eindhoven campus in Eindhoven. AD vehicles drive towards the Automotive campus in Helmond covering road distance of approximately 10 km, of which 6km is a high speed (100 kmph speed limit) road segment on A270/N270. 5G networks are provided by three partners namely KPN, TNO, TU/e. Commercial 5G network with 6 gNBs from KPN will serve along the trial site. 5G small cells provided by TU/e will cover university campus, Eindhoven and a 5G research network with two gNBs along the trial site closer to the Automotive Campus, Helmond will be provided by TNO. These three 5G networks will provide a multi-Public Land Mobile Network (PLMN) environment for testing services in a cross-border setup. Additional road side units such as fixed camera every 100m and ITS-G5 units every 500 m in the A270/N270 segment and intelligent traffic light controllers along the route with their C-ITS services makes the trial site an ideal location for testing and evaluation.

AD vehicles will be provided by three 5G-Mobix partners, namely VTT, TU/e, and SYSSBV (upon getting road exemptions) and one connected vehicle by TNO. The vehicles capable of ITS-G5 and 4G communication will be upgraded to 5G C-V2X communication capabilities. In-vehicle platforms and services will be developed and tested locally in the campuses of respective participating member states (i.e. the Netherlands and Finland) and will be brought to trial site for evaluation.

13.5. Chinese (CN) Trial Site

Table 58 Chinese location overview

Trial site class	Pre-deployment
Country/Countries	China
City/Cities	Jinan

The Jinan urban trial site is located in Shandong Academy of Sciences, which is the north-western part of Shandong province, about 400 kilometres south of the national capital of Beijing. Jinan city is the capital of Shandong province in Eastern China. The area of present-day Jinan has played an important role in the history of the region from the earliest beginnings of civilization and has evolved into a major national administrative, economic, and transportation hub. The local traffic condition is ideal for evaluation of 5G-MOBIX CCAM, where Jinan city is one of the most congested cities in China.

Figure 53 The China pre-deployment trial site.

13.6. Korean (KR) Trial Site

Table 59 Korean location overview

Trial site class	Pre-deployment
Country/Countries	Korea
City/Cities	Yeonggwang

An urban-type-proving ground located in Yeonggwang, Korea, will be provided by KATECH and will be constructed by end of 2019. It consists of various type of test roads such intersection, pebble road, test hills, circle road with real time monitoring system based on V2X network such as mmWave-band 5G NR, Wi-Fi, WAVE, NFV and etc. The proving ground is designed to test various functions for connected and automated vehicle such as blocking GPS signal, providing moving hotspot (or tethering), traffic light control, and collision avoidance at the cross-section areas. The 5G infrastructures within this trial site are facilitated by another national project (years 2018 – 2022). The national project includes mobile network provider (KMW, Korea Micro Wave), Korean operator (SKT) which will cooperate with 5G-MOBIX Korean partners internally. The Younggwang proving ground will be targeted to be become local testbed to pilot and to validate the not only Korean use cases, but also to be open proving ground used in all the national and international project.

Figure 54 The Korea pre-deployment urban type trial site.

14. ANNEX 3: ADDITIONAL INFORMATION ABOUT USER STORIES

14.1. UCC#1: Advanced Driving

14.1.1. UCC#1, US#1: Complex manoeuvres in cross-border settings (ES)

14.1.1.1. Motivation

In the scope of CAD (Connected and Automated Driving), connectivity and road sensing technologies will provide an extra perception layer to automated vehicles, in order to guarantee the safety and provide a more comfortable solution to the driver.

At the same time, a key element in the automated driving is the availability of an HD-Map, that describes not only a high definition of the road (description, lanes, references, attributes, hazards, road works, etc.) but also is able to have it updated in real time, in order to show changes in the lane path or other updates as soon as they occur.

14.1.1.2. Description

Table 60 Overview of Complex manoeuvres in cross-border settings user story

Use Case Category	Advanced Driving
User Story Leader	CTAG
Other partners	DGT, Telefónica I+D, Nokia Bell Labs, Dekra, UMU, Vigo, CCG, NOKIA PT, NOS, INFRAPT, IT, ISEL, SIEMENS, A-TO-B, NORTE, TIS and IMT
Objective	To execute merge manoeuvre according to the traffic flow of the target lane
Actors Scenario 1	Autonomous vehicle Communication unit Road sensing technologies (e.g. traffic radar) MEC node ADAS system
Pre-conditions Scenario 1	• Autonomous vehicle shall be equipped with a communication unit connected to the 5G network and connected to the vehicle CAN data related with vehicle attributes (speed, acceleration, position, size, etc.).

	• Other vehicles shall be driving in the target lane of the lane merge scenario. • Other vehicles shall be equipped with a communication unit connected to the 5G network and connected to the vehicle CAN data related with vehicle attributes (speed, acceleration, position, size, etc.). • Road-side infrastructure shall be equipped with additional sensors (e.g. traffic radar) to detect other vehicles in the target lane. • Road sensing technologies shall be equipped with a communication unit connected to the 5G network. • A MEC node is available and enabled to forward vehicle data between the vehicles.
User Story flow Scenario 1	1. Vehicles driving in the highway share their attributes in real time, with the nearby vehicles, using the capabilities of 5G Network and the MEC node. 2. The road sensing technologies also disseminate information regarding vehicles driving in the highway by using the capabilities of 5G network. 3. An autonomous vehicle is driving towards the lane merge scenario. 4. The autonomous vehicle receives the information shared by the road-side infrastructure and by the other vehicles according to their attributes. 5. ADAS system of the autonomous vehicle analyses the information received and takes decisions about the best speed to safely incorporate at the highway lane. 6. In case there is not enough space between vehicles, autonomous vehicle will reduce its speed (stopping if necessary) in order to perform a safely and comfortable manoeuvre.
Post conditions Scenario 1	Cooperative Lane merge is done.
Actors Scenario 2	Autonomous vehicle Communication unit Road sensing technologies (e.g. traffic radar) MEC node ADAS system
Pre-conditions Scenario 2	• Autonomous vehicle shall be equipped with a communication unit connected to the 5G network and connected to the vehicle CAN data related with vehicle attributes (speed, acceleration, position, size, etc).

	• Other vehicles shall be driving in the same road of the autonomous vehicle (in front or behind, faster or slower). • Other vehicles shall be equipped with a communication unit connected to the 5G network and connected to the vehicle CAN data related with vehicle attributes (speed, acceleration, position, size, etc). • Road-side infrastructure shall be equipped with additional sensors (e.g. traffic radar) to detect vehicles and measure their attributes. • Road sensing technologies shall be equipped with a communication unit connected to the 5G network. • A MEC node is available and enabled to forward vehicle data between the vehicles.
User Story flow Scenario 2	1. Vehicles driving in the road share their attributes in real time, with the nearby vehicles, using the capabilities of 5G network and the MEC node. 2. The road sensing technologies also disseminate information regarding vehicles driving in the highway by using the capabilities of 5G network. 3. An autonomous vehicle is driving faster than the vehicles driving in the same lane, in front of it. 4. The autonomous vehicle receives the information shared by the road-side infrastructure and by the other vehicles according to their attributes. 5. ADAS system of the autonomous vehicle analyses the information received and triggers a safely automated overtaking manoeuvre. 6. In case the autonomous automated overtaking manoeuvre is not safely enough to be performed, autonomous vehicle will adapt its speed in order to drive behind the next vehicle.
Post conditions Scenario 2	Potential accident has been avoided. Overtaking manoeuvre is analysed.
Actors Scenario 3	• Autonomous vehicle • Driver • ITS-Centre • Communication unit • ADAS system • Sensor devices such as lasers, cameras and radars

Pre-conditions Scenario 3	• Autonomous vehicles shall be equipped with a communication unit connected to the 5G network and connected to the vehicle ADAS system. • Autonomous vehicles shall be equipped with an HD-Map Unit that contains the information of the route to be followed by the vehicle. • An ITS-Centre is available and ready to receive, update and share HD-Map information. • Other autonomous vehicle is driving the same route as the first autonomous vehicle but keeping a long distance between them (>2 Km).
User Story flow Scenario 3	1. An autonomous vehicle is driving in a highway road. 2. The ITS-Centre notifies about a road works event that takes place in the route that the autonomous vehicle is following. 3. The autonomous vehicle receives the information and checks if its HD-Map has been updated with the related road works information. 4. In case the HD-Map has not been updated, automated vehicle requests the driver to take back the control of the driving. 5. The driver drives the vehicle through the road works area, and the autonomous system records the new path based on its sensors information. 6. When the vehicle passes completely the road works event, the autonomous systems sends recorded data to the ITS-Centre. 7. The ITS-Centre receives the data of the changed route and generates and updates the HD-Maps information for the road works area. 8. The ITS-Centre shares the new HD-Map with other relevant vehicles. 9. Other upcoming vehicles receive the updated HD-Maps from the ITS-Centre and follow the new path.
Alternative flows Scenario 3	In case the HD-Map has already been updated including road works path data, autonomous vehicle follows the path through road works area.
Post conditions Scenario 3	• Enhanced HD-Map service information with data provided by vehicles and road-side infrastructure. • Improvement in safety by giving a more secure path in a road works event

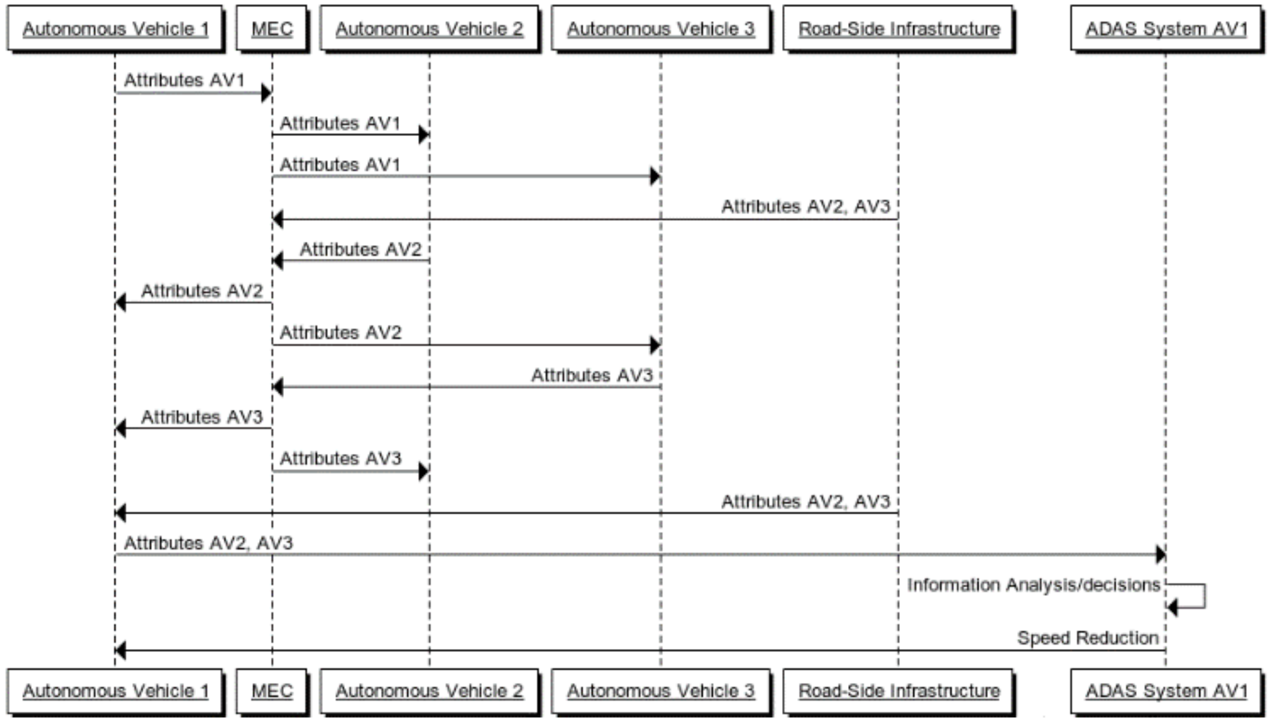

Figure 55 Sequence diagram for Scenario 1

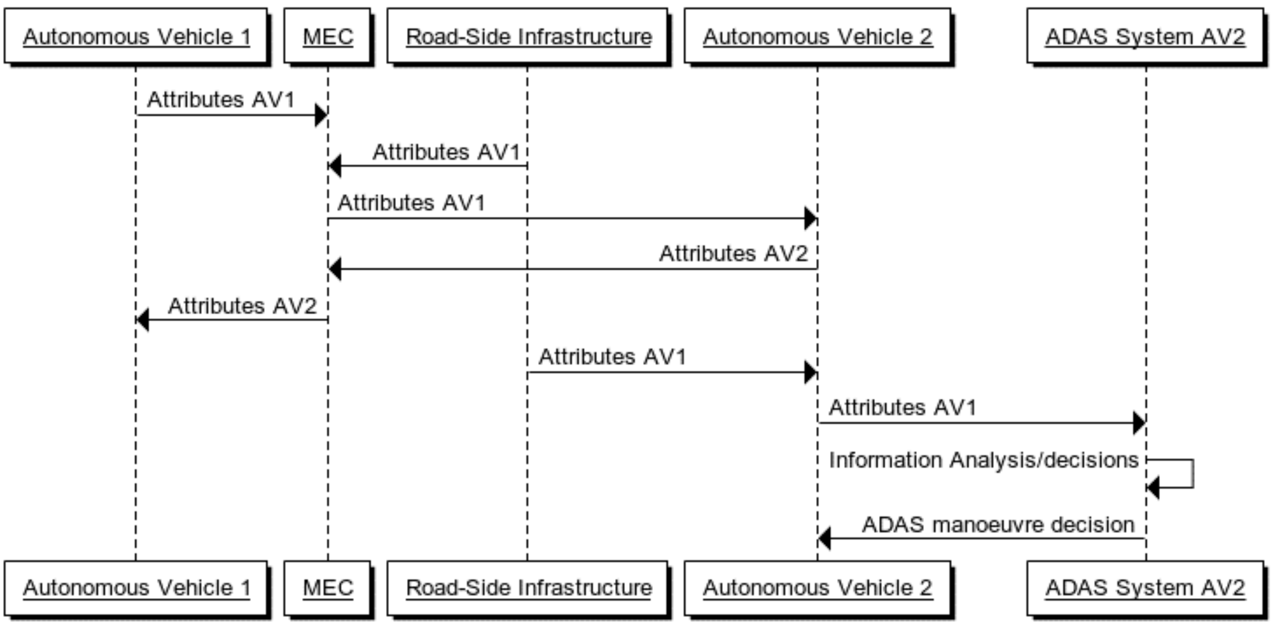

Figure 56 Sequence diagram for Scenario 2

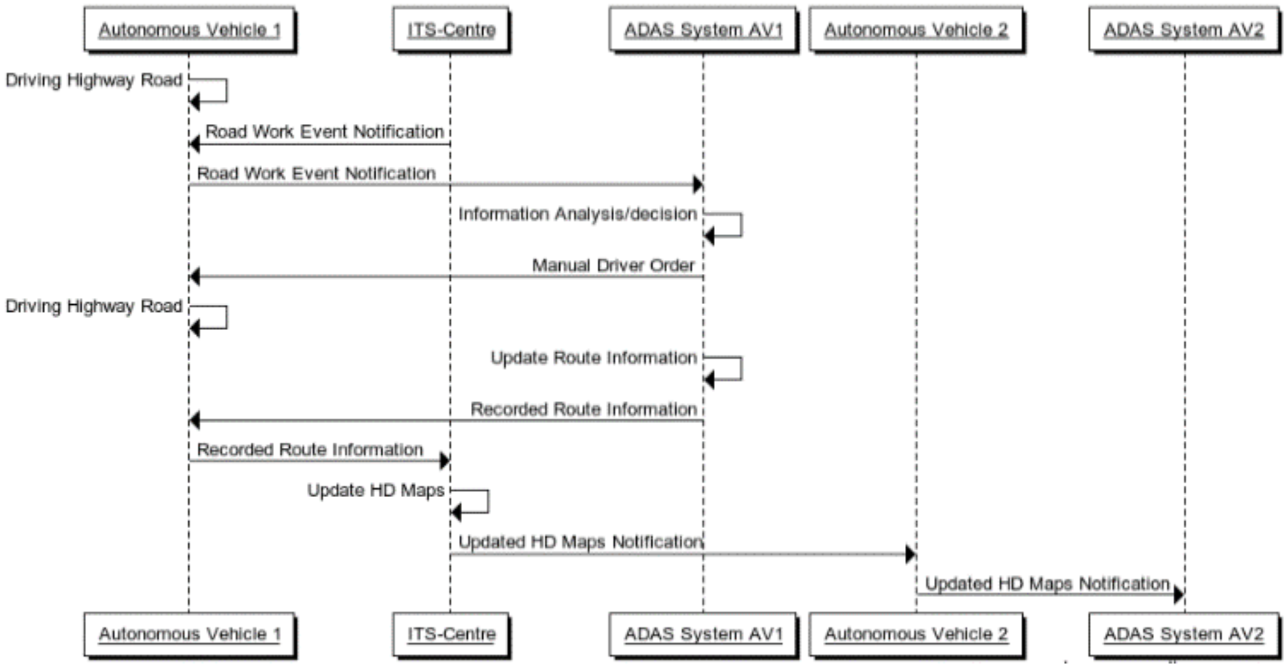

Figure 57 Sequence diagram for Scenario 3.

14.1.1.3. *Beyond state of the art*

This user story will improve safety and comfortability on connected and automated vehicles by giving them, not only an extra perception layer, but also a real-time updated high definition map of the road. Advances in communication technology that 5G brings (like low latency, high bandwidth, massive devices capacity or multicast/broadcast capability) will help to become real the scenarios considered in this user story.

14.1.1.4. *5G services*

Table 61 Overview of 5G services to be implemented in user story

5G service	Implementation
eMBB	Yes, to allow the big amount of data related to the HD maps to be uploaded/downloaded between vehicles and the ITS-Centre.
URLLC	Yes, to avoid delays and high latencies on vehicle-to-vehicle or vehicle-to-infrastructure communication.
C-RAN	Yes
Network Slicing	Yes, to guarantee the quality of service for the communication channel.

14.1.2. UCC#1, US#2: Infrastructure-assisted advanced driving (FR)

14.1.2.1. Motivation

Investigating advanced vehicle control and safety systems has become the key development within C-ITS research fields and the automotive industry. The ultimate purpose of such investigation is to implement various types of driving-assistance systems, providing an opportunity to relieve the driver from driving fatigue and the monotonous routines of driving tasks. Among these tasks, lane-change manoeuvres are used as primitives for performing complex operations such as avoiding obstacles or overtaking vehicles ahead. Lane-change manoeuvre may cause numerous fatal crashes because of the unsafe diversion space from the original lane, poor visibility when passing a vehicle, or erroneous judgment in returning to the lane.

Hence, the ultimate goal of the automated lane-change user story is to guarantee the safety of the driver as well as other vehicles when performing such an action. Performing such manoeuvres safely will require cooperation among vehicles as well as infrastructure, to create the necessary gap to allow the automated vehicle to quickly merge onto the target lane in time to avoid a collision with a successor vehicle or an obstacle.

In addition, in the case of approaching a cross-border zone in the highway, cooperation between infrastructure and automated vehicle is needed to exchange up to date information about the different toll gates and lane categories (heavy trucks, automated vehicles, payment method, etc) available on the other side of the border.

By using 5G, vehicles and infrastructure are able to exchange raw data with the automated vehicle with very high reliability (URLLC), which is not feasible with previous generation mobile networks, in order to avoid hazardous situations. The use of MEC technology allows local data analysis for faster decisions. MEC requires massive amount of data (eMBB) to be collected and dynamic map layers require low latencies (URLLC) to keep the database up-to-date. Moreover, URLCC service is required when the automated vehicle (vehicle ahead) will communicate with the connected one (vehicle behind coming in the same direction) to negotiate the lane change manoeuvre. Specifically, the system will showcase the added value of using 5G services like eMBB and URLCC technologies for automated overtaking manoeuvre.

14.1.2.2. Detailed description

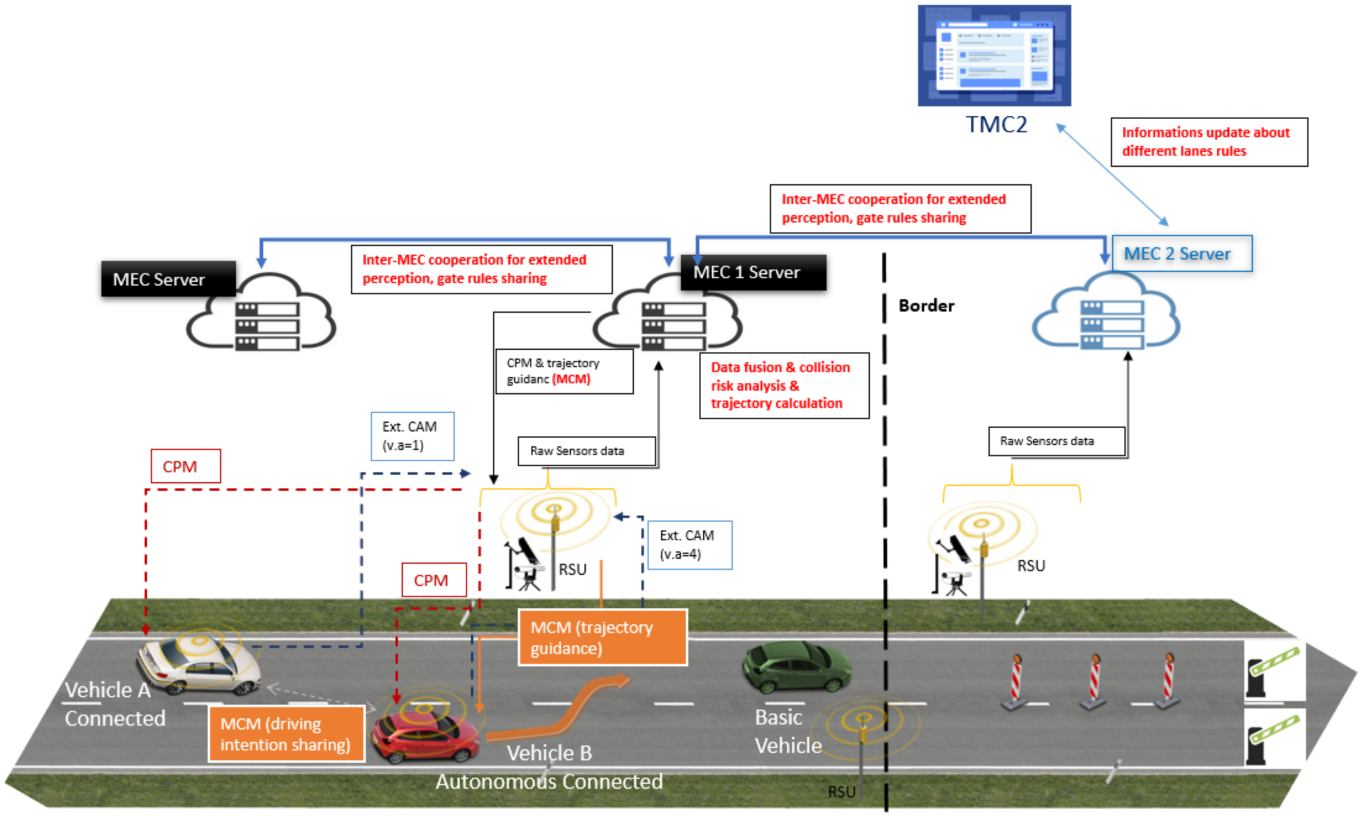

Figure 58:Example of the automated overtaking user story from the FR corridor.

Table 62: Overview of Infrastructure-assisted advanced driving user story

Use Case Category	Advanced Driving
User Story Leader	VEDECOM
Other partners	ERICSSON, AKKA, VALEO, La Croix, Bouygues, Orange, UTAC/CERAM
Objective	Improve safety of automated driving manoeuvres by coordinating driving trajectories
Actors	Vehicle A, Vehicle B, MEC1, MEC2, TMC1, TMC2
Pre-conditions	• Vehicle A is a connected vehicle • Vehicle B is an automated and connected vehicle • Vehicles and road side infrastructure support message exchange over 5G, C-V2X • Separation signs between the different types of lanes

User Story flow	1. RSUs and road sensors send data to MEC 2 2. TMC 2 informs MEC 2 about the up to date categories of toll gate (heavy trucks, CAV, payment methods) 3. MEC 2 proceeds with data fusion (from TMC 2, RSU and road sensors) and data analysis 4. MEC 2 shares data with MEC 1 5. MEC 1 detects that Vehicle B is approaching the cross border (CAV is sending CAMs with its position, speed) 6. MEC 1 treats data received from MEC2, RSUs as well as road sensors (data fusion, collision risk analysis) and takes the lane change decision 7. MEC1 sends MCM message (trajectory guidance) to Vehicle B to change the lane 8. Vehicle B starts the lane change manoeuvre and informs vehicle A about its driving intention (MCM) 9. Vehicle A confirms the creation of the required safety distance 10. Vehicle B is informed of the creation of required safety lateral distance 11. Vehicle B moves into the selected lane by transmitting continually and periodically its trajectory plan to vehicle A over 5G. 12. The trajectory plan is updated based on the evolution of the manoeuvre and the location of Vehicle A
Post conditions	• Vehicle B performs safely the lane change with the cooperation of Vehicle A according to the MEC recommendations

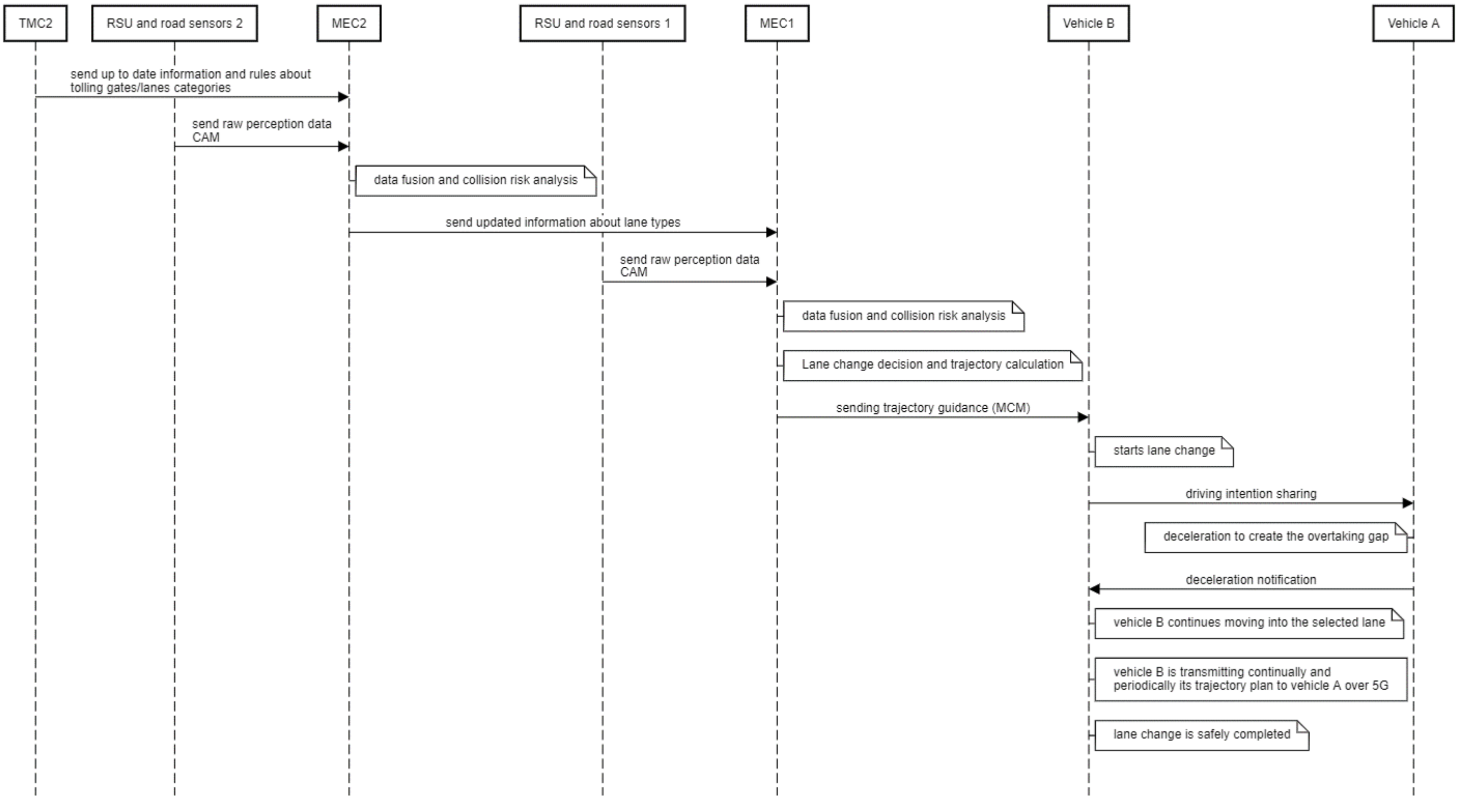

Figure 59: Infrastructure assisted advanced driving sequence diagram

14.1.2.3. *Beyond state of the art*

Current 4G technology cannot offer the required performances needed for the present user story since it needs low latency communications with high reliability between vehicles. In this case, 5G is needed since the bandwidth and latency provided by the network allow for the creation of network slicing and provide a better QoS for safety critical applications. URLLC will be used for low latency exchange between vehicles and infrastructures while eMBB will be used for the 5G positioning system and data sharing when changing the lane and then maintaining a safe distance from the connected vehicle behind.

14.1.2.4. *5G services*

Table 63: Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes. To exchange raw sensors data between vehicles and infrastructure
URLLC	Yes. Low latency data exchange between vehicles

14.1.3. UCC#1, US#3: Cooperative Collision Avoidance (NL)

14.1.3.1. Motivation

Cooperative Collision Avoidance: CoCA is a safety-critical service where communication between vehicles and vehicles and infrastructure are used for Collision Avoidance. 5G technologies provide the required low latency communications environment that is a prerequisite for any safety-critical ITS system or service. Connected and Automated Vehicles (CAV) and intelligent infrastructure solutions together are capable to provide technical and communications support for CoCA.

CoCA will be activated when there is a potential traffic violation, which is assessed considering the traffic light status, and status of existing C-ITS services (to make note that these are operational services that cannot be deactivated). The triggering of the CoCa application is very time critical, and it needs to intervene in time to initiate evasive action. For that purpose, the speeds and position of approach vehicles towards the intersection need also to be assessed with great precision. The 5G technology in conjunction with road-side systems will also allow for improved assessment of the vehicle trajectories at the intersection. The ego vehicle must be able to utilise both its own trajectory and timing data as well as the alter vehicles' precise location and intended direction and speed to avoid colliding with each other.

14.1.3.2. Detailed description

Table 64 Overview of Cooperative Collision Avoidance user story

Use Case Category	Advanced Driving
User Story Leader	VTT
Other partners	TNO, KPN, SISSBV
Objective	High bandwidth, low latency data exchange for safety-critical application of Cooperative Collision Avoidance at the highway intelligent intersection
Actors	CAV vehicles, 5G operators, roadside sensors
Pre-conditions	• Vehicles A and B support message exchange via 3GPP V2X communication. • Vehicles A and B support basis for V2X safety application (CAM, DENM etc.) so they already know their relative positions. • With relative positions, Vehicles A and B can operate CoCA application

User Story flow	1. Vehicle A is a foreign registered CAV, and Vehicle B is a Dutch registered CAV 2. Vehicle A or B detects the risk of collision. 3. V2X application of vehicle A detects a risk of collision. Vehicle A's application exchanges CoCA related messages (trajectories, sensor data, brake commands etc.) via 3GPP V2X communication service. 4. Vehicle B confirm on application layer to vehicle A the coordinated manoeuvre for CoCA by transmitting messages via 3GPP communication service
Post conditions	• Vehicles A and B perform coordinated manoeuvre

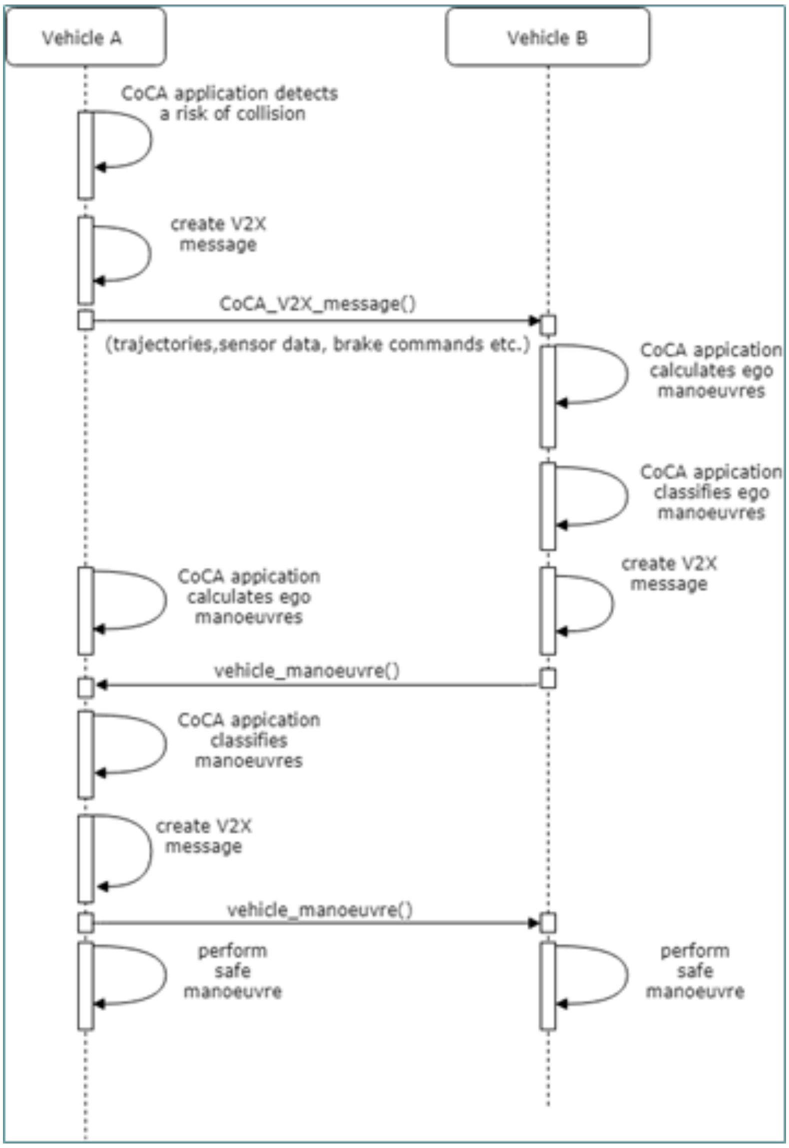

Figure 60 Sequence diagram of Cooperative Collision Avoidance user story

14.1.3.3. Beyond state of the art

The ultimate target of the project is deploying the services and applications functionalities over 5G Network. 5G is needed due to the limitations of LTE technology regarding the bandwidth and latency. Also, 5G allow for the creation of network slicing and provide a better QoS for safety-critical applications.

MEC will be used to orchestrate the communications, applications and functionalities of CoCA.

URLLC will be used for low latency data exchange between vehicles and infrastructures while eMBB will be used for the 5G positioning system and data sharing.

14.1.3.4. *5G services*

Table 65 Overview of 5G services to be implemented in the CoCA user story

5G service	Implementation
eMBB	Yes, to exchange raw sensors data between vehicles and infrastructure
URLLC	Yes, low latency exchange between road entities

14.1.4. UCC#1, US#4: Cloud-assisted advanced driving (CN)

14.1.4.1. *Motivation*

In our automated driving, we mainly consider coordinating overtaking and collision avoidance, and change driving mode, which are key enabling techniques for road safety and traffic efficiency services.

This case tries to enable the vehicle to assess the probability of an accident better and coordinate the exchange of information in addition to safety information, sensor data, braking and acceleration command lists, horizontal and vertical control in the application of road traffic flow through V2X communication.

14.1.4.2. *Detailed description*

Table 66 Overview of Cloud-assisted advanced driving

Use Case Category	Advanced Driving
User Story Leader	DUT(DALIAN)
Other partners	SDIA (SHANDONG), CNHTC, DDET, QILUTIG
Objective	To achieve coordinated driving between autonomous vehicles
Actors	Vehicles A and B, RSU, ME
Pre-conditions	Vehicles A and B support message exchange via 3GPP V2X communication.
User Story flow	Vehicle A receives the overtaking order or detects the obstacles 1. Vehicle A sends the overtaking or obstacle information to Vehicle B 2. Vehicle B sends back instant information, including vehicle position, speed, course angle, etc. 3. RSU receives the information, fuse them to send to a cloud server 4. Cloud server decides according to the information and carries out corresponding path planning.

Postconditions	Vehicles A and B perform the coordinated maneuver.

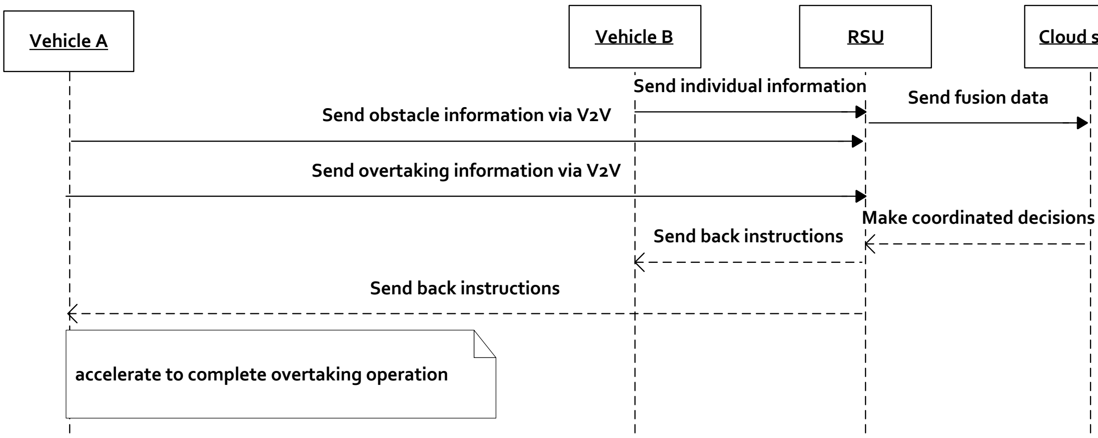

Figure 61 Sequence diagram of Cloud-assisted advanced driving

14.1.4.3. *Beyond state of the art*

Our current L3 vehicles employed DSRC V2X solutions. The 5G-MOBIX technology deployed in this user story has long coverage range, ultra-low latency, and ultra-reliable reliability, and will enable L4 Autonomous Driving.

14.1.4.4. *5G services*

Table 67 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes. The remote center can receive HD videos and take control of the vehicles.
URLLC	Yes. The collected data should be delivered by ultra-low latency and high reliable communication in case of emergency.

14.2. UCC#2: Vehicles Platooning

14.2.1. UCC#2, US#1: Platooning with "see what I see" functionality in cross-border settings (GR-TR)

14.2.1.1. Motivation

A platoon is a group of vehicles that "move like a train with virtual strings attached between each other" [1]. In order to better make use of road space and render transportation of goods more efficient, a convoy is formed in which the vehicles move much closer together than can be safely achieved by human drivers [2], resulting in significant fuel consumption savings, as well [1]. To maintain the distance between the vehicles and the operation of the platoon, the vehicles need to share their states such as location, speed, heading and their intentions such as braking, acceleration, etc over the C-V2X links established between them, which does not necessarily require a network operator to be present, and thus a SIM card.

Despite the numerous advantages of platooning, from the point of view of the vehicles that are at the back, following the lead vehicle in a platoon (the gap distance translated to time is 0.3 seconds or even shorter) can cause lack of attention and anxiety while driving, since trailers are wide and high enough to cover driver sight. These problems are quite common also among today's truck drivers. To circumvent them, a "see-what-I-see" application will be designed and implemented for truck platooning, which will be providing the road view of the leader truck to the others in the platoon. Here, the goal is to enable the trailing truck drivers to be alert and aware of the road conditions, which is especially critical for SAE L4 and below autonomous vehicles that might need human intervention at some point.

The resolution requirement for the "see-what-I-see" functionality is that a 4K – Ultra HD high quality and precise video is shared with the follower vehicle drivers. Since a huge bandwidth (eMBB) is needed to transfer such a high volume of data coupled with very low latency (URLLC) due to the real-time nature of the video transmission from the leader truck to the others in the platoon, 5G technology is a must for this application to be realized. Current technology falls short of the bandwidth and latency requirements of the "see-what-I-see" functionality to be developed for the platoons as described.

In order to fully demonstrate a cross-border platooning scenario with "see-what-I-see" functionality, "truck routing in customs site" between Turkey and Greece is included in the user story, as well, which will enable the transfer of the platoon members from one end of the border to the other much faster. As can be seen in Figure 1, the border between the two countries is characterized with long queues, traffic jam, and strict controls such as document and X-ray checks, demanding that such an addition to the user story is made. The process of passing from Turkey to Greece requires that the truck drivers stop more than once: Document delivery at the customs site entrance, entire truck x-ray check if customs officer has the decision to do so, customs counters to receive/deliver "all clear to pass" documents are some of the stop points.

By deploying additional sensors at the customs site to apply the sensor fusion technique for the "truck routing in customs site", the tough manoeuvres that are to be handled in a small area due to the other vehicle and pedestrian traffic, will be carried out autonomously, and the truck will be able to move from one point to another without the driver. This will enable the driver to save time to expedite other procedures required to get border pass approval while, at the same time, traffic efficiency will be increased, and the average vehicle border crossing time as well as the number of traffic accidents due to human error will be decreased at customs sites.

Figure 62 How does the GR-TR Border look like?

Traffic flow example at the Turkish customs site can be seen in Figure 2. Note that this is just a descriptive figure of the customs site to show the related infrastructure and functionality, drawn not to scale.

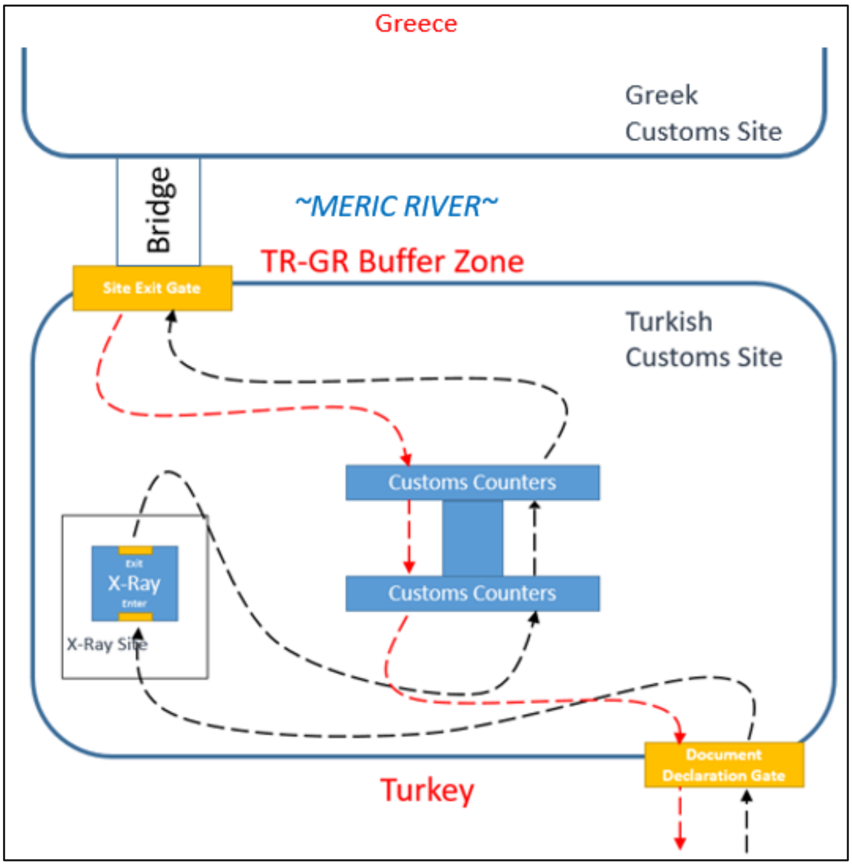

Figure 63 Traffic Flow between the GR-TR Borders

14.2.1.2. *Detailed description*

Table 68 Overview of Platooning with "see what I see" functionality in cross-border settings user story

Use Case Category	Vehicles Platooning
User Story Leader	Ford Otosan
Other partners	IMEC, Turkcell, Cosmote, Ericsson TR, Ericsson GR
Objective	Real time 4K UHD video transfer between trucks in a platoon and autonomously route a truck in customs site
Actors	• Autonomous Truck • 5G Telecom Networks • "See-what-I-see" application • "Truck-routing" application
Pre-conditions	• All the vehicles support C-V2X (PC5 & Uu) communication.

	• Each vehicle has a unique label for identification when interacting with others, the "see-what-I-see" and "truck routing" application. • The platoon has more than one active vehicle, driving in the same lane. All the platoon members are within the communication range of its direct neighbour, which is also a member of the platoon. • The direction of the platoon is towards the borders between Turkey and Greece. • Platoon vehicles moves a zone that covered by 5G technology.
User Story flow	*Platooning with "see-what-I-see" functionality* 1. The platoon leader transfers vehicle data, such as speed, brake, position to the follower vehicles through the respective OBUs to sustain the operation of the platoon. 2. The platoon is created, and the "see-what-I-see" application is informed about this decision, which in return sends a confirmation message to the leading vehicle. 3. The platoon leader sends the compressed UHD camera image of the road as seen from its windshield to the application through the 5G network, which consists of the 5G base station (gNB) and the vEPC (i.e., 5G EPC which can connect to gNBs). 4. The application sends this video stream to the follower vehicle OBUs again through the 5G network. Normally, the vEPC and most likely the base station serving the following vehicles are expected to be the same as the leader. 5. The OBUs of the follower vehicles transfer the video stream to the in-vehicle display. 6. Platoon is dissolved when vehicles reach to TR-GR border. *Truck routing in customs site* 1. Driver initiates "truck routing" application. 2. All sensory information (i.e., from the vehicles and the environment) at the customs site will be collected, and sent to the edge through the 5G network. 3. Collected data will be transferred to an application server, which is in charge of processing and aggregating the information collected from different sensors and construct a high definition map of the environment. The role of the application at the server is to assist the vehicles during their checkpoint visits at the customs site, calculating the dynamic safe waypoints individually for each of the vehicles, where a continuous flow of information between the application, the sensors and the vehicles will take place. 4. The 5G network will get the calculated trajectory data from the application server and transfer it to the OBUs of the vehicles, which are tasked with starting an internal set of operations to

	complete the manoeuvring of the vehicles. Internally, each OBU will have the following mode of operation: a. The OBU will gather safe waypoint data and transmit it to the Vehicle Central Control Unit (VCCU), a proprietary module whose software development is done by Ford Otosan, via the vehicle Ethernet connection. b. The VCCU will send the required Controller Area Network (CAN) messages to the other electrical control units (ECU) of the vehicle, such as the brake and the steering ECU. c. The related ECU receiving the CAN messages will perform the pre-defined manoeuvring. *Moving into Country 1 from Country 2: Platooning with "see-what-I-see" functionality.* 1. The customs tasks and all checkpoint visits are completed, and thus the vehicles leave the customs area to start the platooning operation again as in Steps 1-5. 2. The platoon roams from one operator to the other when the signal strength received from the other is higher, with no interruption observed for the "see-what-I-see" functionality. In Step 4, an extreme scenario may be observed, during which while the leading vehicle roams into the operator in Country 1, the trailing vehicles are still in Country 2. This is depicted in the sequence diagram shown in Figure 4 below.
Post conditions	• The platoon follower vehicles can view the road, which lies ahead the leader vehicle of the platoon. • The trucks move from one country to another in the fastest and the most comfortable way possible. • Driver experience is enhanced. • Accelerated passage across the borders.

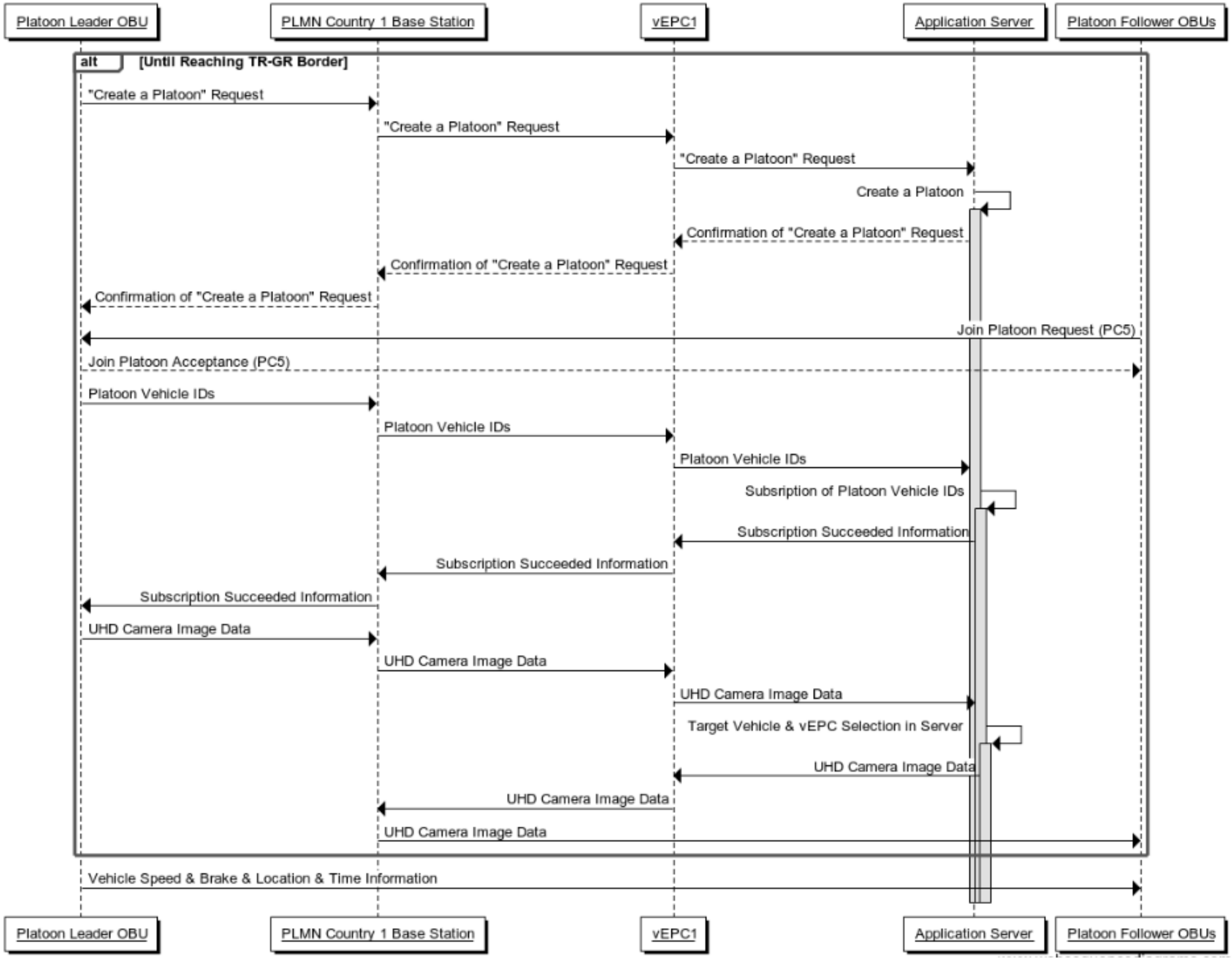

Figure 64 Sequence diagram for the platooning user story with "see-what-I-see" functionality (Until Platoon Reaching TR-GR Border)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 825496.

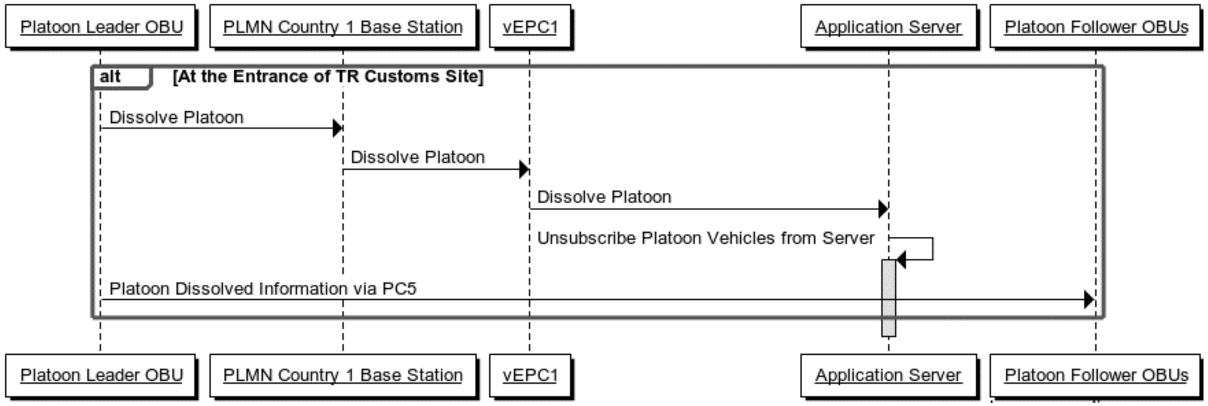

Figure 65 Sequence diagram for the platooning user story with "see-what-I-see" functionality (At the Entrance of TR Custom Site)

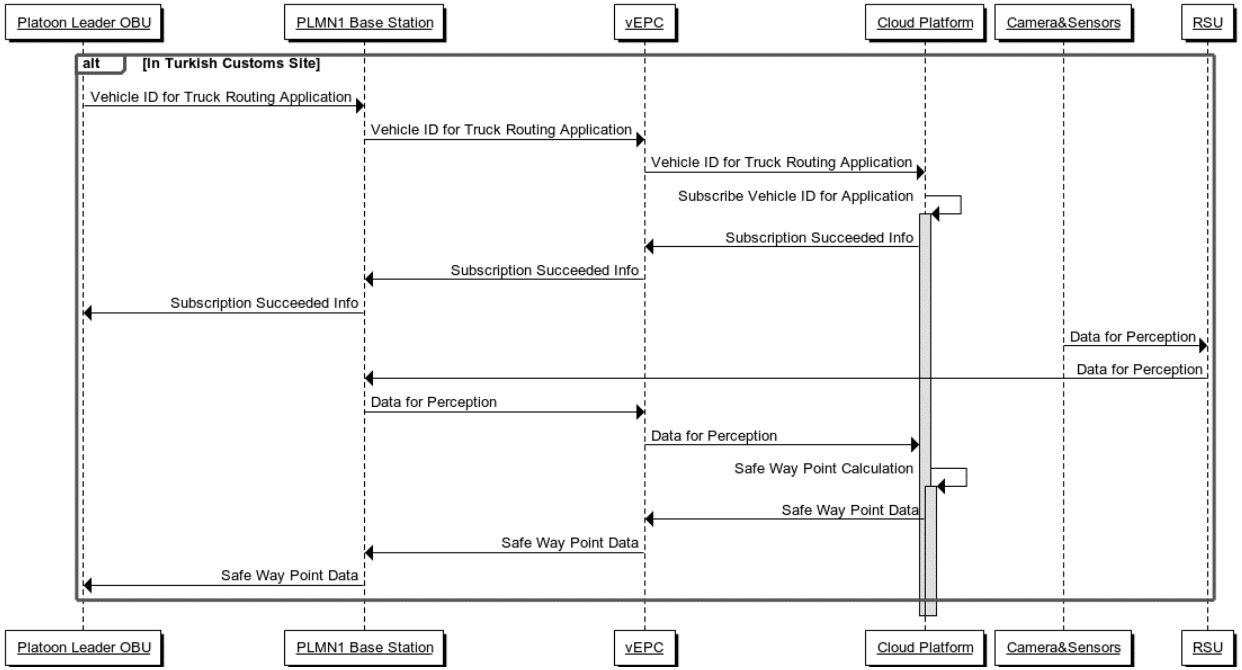

Figure 66 Sequence diagram for the "truck routing in customs site" functionality

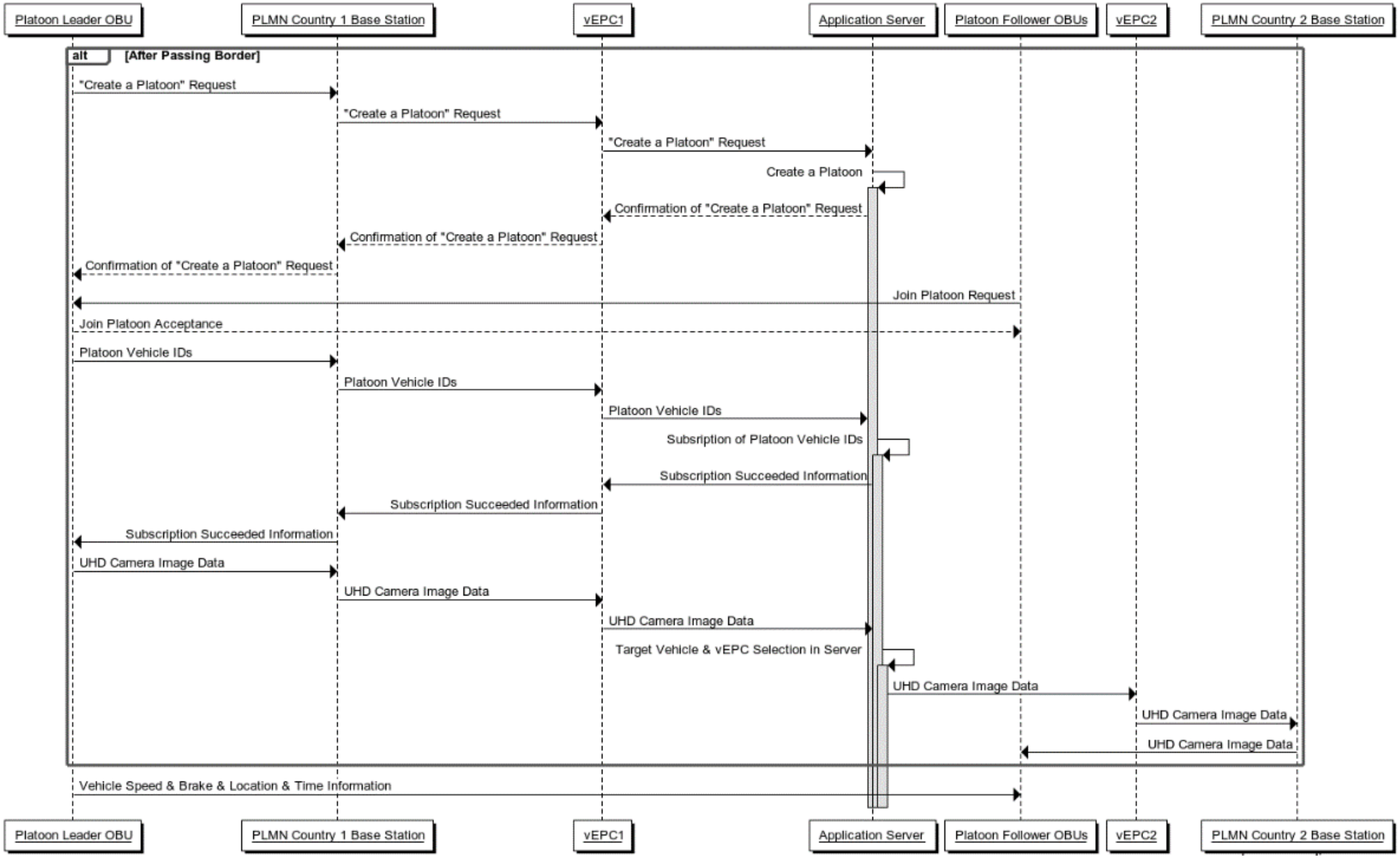

Figure 67 Sequence diagram for the platooning user story with "see-what-I-see" functionality (After Passing the TR-GR Border)

14.2.1.3. *Beyond state of the art*

With the help of the enormous data transfer capability of the 5G network, this user story can be evolved in the future to encompass different purposes. For example, 4K video data can be collected from the lead vehicle and transferred to a local centre to observe the driver – vehicle status or with the addition of an extra in-cabin camera, driver health and security can be tracked remotely. Fleet owners and insurance companies can take advantage of such systems in the future, even making it mandatory for all vehicles.

14.2.1.4. *5G services*

Table 69 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes. The high bandwidth requirements of the video generated by the camera viewing the road that lies ahead of the leading truck in the platoon and data generated by sensors to route truck in customs site.
URLLC	Yes. The transmission of the video has to be performed in real-time to prevent any incidents that may result from a sudden intervention of one of the drivers in the trailing trucks in the platoon to leave the platoon and get on the road.

14.2.2. UCC#2, US#2: eRSU-assisted platooning (DE)

14.2.2.1. *Motivation*

The German trial site is also called "Protocol Road" that leads to the German Parliament and is very often used to drive dignitaries from the airport to the government district. Movement of dignitaries with huge number of vehicles disturbing the normal flow of traffic is a common phenomenon and will also be existing in the autonomous driving era. With the realization of digitized roads, automated & connected vehicles, and talking traffic lights, the efficiency in traffic flow may be achieved alongside road safety. Such vehicle groups pose similar challenges as those highlighted by commonly known platooning use-cases e.g., eMMB relevant, URLLC relevant, seamless MNOs handover, etc. The motivation to execute this user story on the trial site comes from: i) showcasing the autonomously driven protocol vehicles, ii) addressing the platooning challenges for SAE L-4 platoons, iii) studying the need for roadside infrastructure for such platooning, iv) studying the need for sufficient communication coverage, etc. As opposed to typical deployment of the Roadside Units that simply enables the V2X communication, for this user story we rely on the richer roadside unit, that serves as the near edge with additional services for the autonomous driving.

At the trial site, we rely on an extended roadside unit (eRSU), that serves as a near edge with additional services for the autonomous driving. We implement the concept of distributed processing and decision making by contributing with a three-level solution architecture i.e., vehicle level, edge level, and cloud level. At these levels, we create three perceptions namely: Local Dynamic Map, Edge Dynamic Map (created by on-road deployed infrastructure that creates the perception of road segment), and Global Dynamic Map that creates a global perception of the trial sites. These three perception maps interact and populate the LDM by making use of 4G communication technologies, which impose the limitations of delay and bandwidth. With 5G deployed, limitations of the platooning user story will be addressed by: i) availability of greater capacity that allows the population of LDMs of all vehicles with high quality information, ii) flexible control plane that allows efficient execution of network operations, iii) reduced communication delay that enables the real-time information exchange between EDM and LDM, etc. Last but not the least, the use-case scenario aligns well with the cross-border settings.

Contexts of the German trial site will be incorporated in this use-case with full range of complexity relying on 5G infrastructure to provide the required data transmission frequencies, low-latency, trusted, secure and fail-safe data transmission protocols and harmonised data syntax that ensures safe interoperability. This use-case will showcase the roles of 5G services eMMB, URLLC, etc., in providing real-time sensor data and ITS services to automated and connected vehicles:

- Enriching the perception of CCAM by feeding in the data from roadside sensors including: traffic analysis, road-condition, object detection, traffic light, and intelligent street lights etc.,
- Utilizing 5G's access agnostic, virtualized control plane hosted close to the road-side to meet the URLLC requirements of safety-related vehicle-roadside sensor interactions.
- Orchestrating the 5G services near the edge and complementing those with AI approaches to assist lane-keeping / leaving, speed adaptation, and turning decisions of CCAM vehicles.

14.2.2.2. *Detailed description*

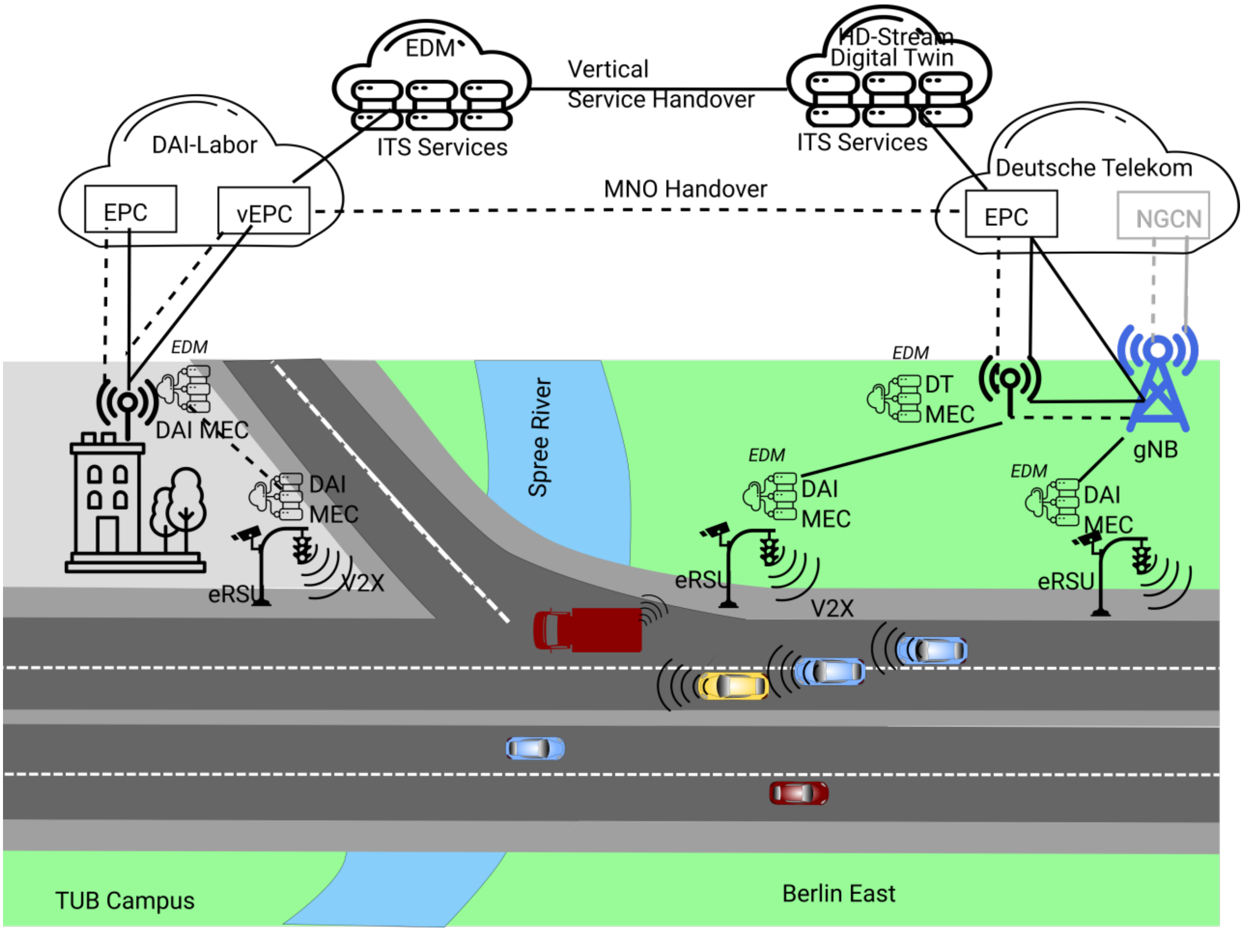

Figure 68 5G supported autonomous overtaking manoeuvre during platooning with MNOs handover

Table 70 Overview of eRSU-assisted platooning user story

Use Case Category	Platooning
User Story Leader	TUB
Other partners	ALL German partners
Objective	5G supported autonomous overtaking manoeuvre during platooning with MNOs handover.
Actors	Vehicle A (platoon leader), Vehicle B (truck), Vehicle C
Pre-conditions	• Vehicle A, B and C support 5G connectivity

	• Two eRSUs deployed nearby with EDM generation capability
User Story flow	1. A platooning AVs group operates normally (3GPP eV2X support) in the reserved bus lane. 2. The truck (vehicle B) signals its intension to turn right at the next junction. 3. The platoon leader request real-time EDM & ITS services and calculate overtaking manoeuvre (3GPP Emergency trajectory alignment & intersection safety information). 4. MNOs and ITS services handover connectivity and application context during manoeuvre. 5. The platoon lead coordinates overtaking manoeuvre (3GPP information exchange within platoon & information sharing for high/full automation). 6. Mis-use-case: not connected truck changes course during platoon overtaking → platoon emergency brake & braking.
Post conditions	• Autonomous vehicle platoon completes overtaking manoeuvre. • The potential crash has been avoided in mis-use-case.

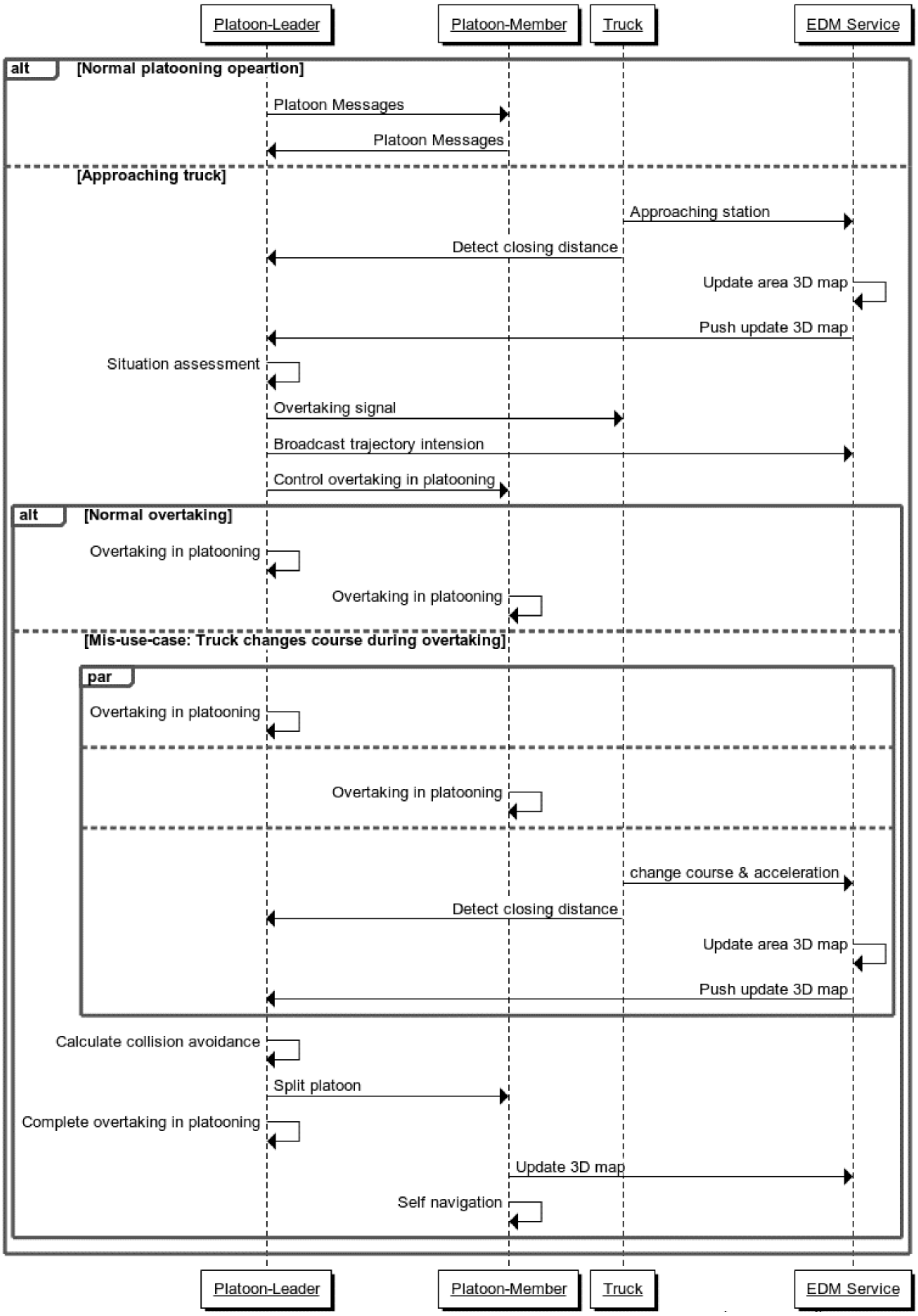

Figure 69 eRSU-assisted platooning sequence diagram

14.2.2.3. *Beyond state of the art*

This use-case showcases the roles of 5G services eMMB, URLLC, etc., in providing real-time sensory data from on-road deployed traffic analysis sensors and ITS services to the vehicles. With the current deployment and concept of Edge Dynamic Map, the user story will allow implementing the platooning user story of L-4 autonomous vehicles. This is to say that through 5G networks will allow the real-time sharing of edge dynamic map with the vehicles. The user story will also study the concept of computation, sensor fusion, decision making at three distributed levels by exploiting the near / far edge of the mobile networks. A distributed middleware platform facilitates the fusion of sensing data for various assisted driving applications. However, current LTE and small-cell based transport networks can provide only limited capability for real-time data communication required to support fully autonomous driving applications. The 5G deployment during 5G-MOBIX project is expected to address QoS limitation of current 4G networks, among others. Additional approaches for intelligent end-to-end orchestration, data fusion and vehicle research will enable the trial and application of SAE L4.

14.2.2.4. *5G services*

Table 71 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes. eMBB slices will be used in this user stories for the transmission of high definition sensing data from street cameras and different types of sensors of the road digitization overlay.
URLLC	Yes. uRLLC slices will be used for the transmission of data from the AVs to the MEC platforms to central cloud for real-time decision making, command and control.
Other	5G slice management and orchestration of appropriate VNFs are required to realize consistent and efficient operations.

14.2.2.5. *References*

[1] https://ec.europa.eu/digital-singlemarket/en/cooperative-connected-and-automated-mobility-Europe

[2] https://www.telekom.com/en/media/media-information/archive/5g-rollout-in-germany-523636

14.2.3. UCC#2, US#3: Cloud-assisted platooning (CN)

14.2.3.1. Motivation

The complexities of urban road traffic flow bring the strong randomness of pedestrian distribution, and the movement state of the pedestrian is more time-varying than that of cars. As one of the main road traffic participants, pedestrians are highly injurious, disabled or even fatal when a traffic accident occurs, so our road safety and traffic efficiency services will mainly care pedestrians.

In this case, we will upgrade the intersection safety information system, which consists of road radar, traffic signals, and LDM servers and RSUs. Based on them, our purpose is to detect pedestrians and avoid accidents.

At this stage, V2X road safety services are applied to traffic systems through roadside units (RSUs). RSUs generate and distribute traffic safety-related messages for road safety and deliver them to vehicles equipped with onboard units (OBUs). In this case, safety information at the intersection involves precise digital map, traffic signal information, pedestrian and vehicles' moving status information and location information, which is generally expressed in LDM (Local Dynamic Map) . The 3GPP system will support an average of 0.5 Mbps in downlink and 50 Mbps in uplink. An RSU will communicate with up to 200 UEs supporting a V2X application. Also, RSU will support 50 packet transmissions per a second with an average message size 450 bytes.

14.2.3.2. Detailed description

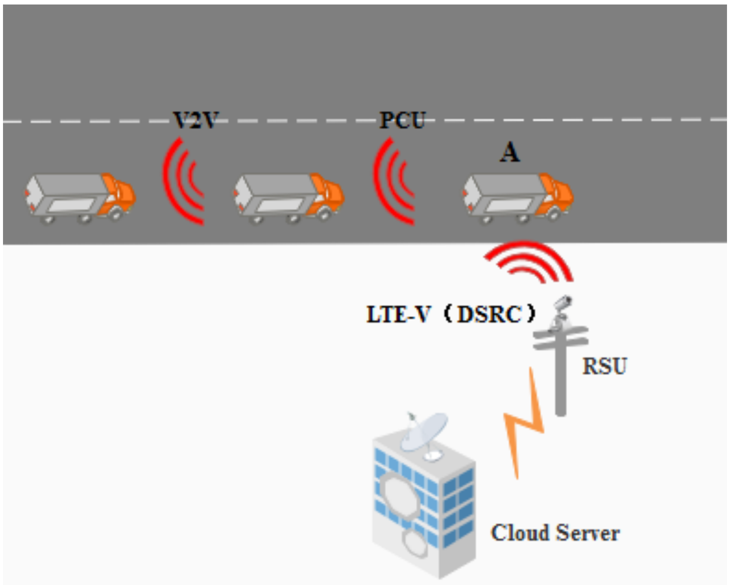

Figure 70 High-level illustration of Cloud-assisted platooning

Table 72 Overview of Cloud-assisted platooning user story

Use Case Category	Vehicles Platooning
User Story Leader	DUT(DALIAN)
Other partners	SDIA(SHANDONG), CNHTC,DDET ,QILUTIG
Objective	Vehicle A detects Pedestrian B and avoids it.
Actors	Vehicle A, Pedestrian B, RSU, LDM server
Pre-conditions	• The road radar or cameras are installed at the intersection, and they will detect the movement of the vehicle and the pedestrians • The RSU will receive the location and movement information on the vehicle and pedestrian and traffic signal information, generate LDM information
User Story flow	1. Vehicle A communicate with others through LET-V(DSRC) 2. Vehicle A sends messages to RSU 3. RSU delivered data to cloud center 4. Center makes a decision back to RSU, and then it delivers them back to Vehicle A. 5. Vehicle A translates messages to its following vehicles via V2V.
Post conditions	• UE will generate vehicle control information for the autonomous vehicle • The autonomous vehicle will avoid the collision by vehicles or pedestrians

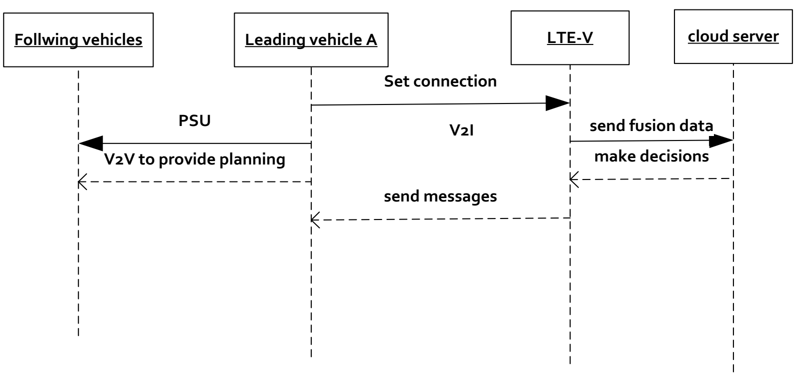

Figure 71 Sequence diagram of user story

14.2.3.3. *Beyond state of the art*

The previous warning method of avoiding accidents is mainly based on vehicle technology, such as image sensor, radar to check the location information of pedestrians, to avoid human-vehicle collisions. The 5G V2X deployed in our user story considers the urban traffic environment where always exist pedestrians beyond the scope of sensor detection, and thus it is possible to avoid the potential risks of human -vehicle conflict.

14.2.3.4. *5G services*

Table 73 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes. Our remote center needs to monitor the whole process by HD videos collected from on board cameras.
URLLC	Yes. The data must be delivered by ultra-low latency and high reliable communication in case of emergency

14.3. UCC#3: Extended Sensors

14.3.1. UCC#3, US#1: Extended Sensors for assisted border-crossing (ES-PT)

14.3.1.1. Motivation

According to recent studies [1], a large portion of time of international transport is wasted at European border crossing in South East Europe (SEE), significantly raising the cost and delivery time of goods and contributing to the segmentation of international logistics. The study in [1] has shown that on average most border crossings take between 30 and 60 minutes but can easily surpass 90 minutes depending on traffic conditions and other factors (counting both waiting and procedural times). The largest portion of this delay is attributed to inefficient flow of information regarding the necessary documentation (33.4%), custom agent's inefficiency (21.9%) and lack of necessary infrastructure and equipment (21.3%). Since border control cannot be alleviated due to security and smuggling concerns, improving the average control time by addressing the weak points of the process can significantly benefit the transport and logistics industry and can greatly reduce both the time and cost of international transportation of goods.

Additionally, border crossing areas with actual customs stations are vibrant and busy multi-actor areas where heterogeneous vehicles, people and infrastructure coexist, leading to a complex environment. Large queues of trucks, large signs, infrastructure (traffic lights, antennas, buildings) can all act as obstacles, minimizing the awareness of the drivers at the borders and amplifying the threat of an accident involving a customs agent, police officer or other more vulnerable road users. The concept of ***assisted cooperative driving*** has the potential to significantly increase the active road safety of the users based on AI/ML techniques which are applied on heterogeneous information from various distributed data sources (UEs, sensors, cameras, etc.) in order to predict certain events and based on this knowledge assist humans by automating certain task (in this case driving). This can be combined with the concept of "live" maps, where the user may be assisted by "live updates" of the maps he/she is using for his/her geolocation / navigation service (GPS, Galileo, etc.) presenting the position of all surrounding road users, potentially providing also additional information regarding the latter (e.g. the users' trajectory, speed) or even updates regarding the road conditions (e.g. road construction ahead, slippery road, etc.).

14.3.1.2. Detailed description

Table 74 Overview of Extended Sensors for assisted border-crossing user story

Use Case Category	Extended Sensors
User Story Leader	WINGS ICT
Other partners	Cosmote, Turkcell, Ericsson GR, Ericsson TR, ICCS, IMEC
Objective	• Border inspection preparation based on predictive CCAM truck routing

	• Secure CCAM truck border crossing with increased inspection confidence • Increased border environment awareness for incoming drivers • Increased border personnel safety
Actors	• Autonomous truck • Border control agents • Additional devices (sensors, cameras, drones, wearables)
Pre-conditions	• Autonomous truck equipped with a multitude of sensors driving towards a border crossing • Border control agents equipped with smart-phones / tablets / wearables • 5G network infrastructure with edge / MEC capabilities available at both sides of the border • Additional infrastructure at the site capable of communicating to the edge / MEC
User Story flow	1. As the truck approaches the border, the truck itself and potentially its cargo (sensors in the cargo hold) start transmitting relevant information towards the border authorities (mMTC). This could take place with a number of different technologies such as GPRS, NB-IoT, 5G-NR slice, etc. 2. Based on the transmitted information and on information gathered by surrounding environmental sensors, the cloud based intelligence can predict the trucks route towards the border, hence initiating the inspection preparations (e.g. download relevant applications from the cloud to the edge / MEC to minimize functional interaction with the network, request information from authorities, setup additional slices if necessary, etc.). The goal is to identify the truck, the kind/type of cargo, the size of the cargo, etc. (**5-10 km before the border crossing**). 3. The information transmitted by the truck can potentially be exchanged over 5G networks with the neighbouring country's authorities and request all relevant information for this truck, driver, cargo etc. For instance, if the truck is registered in the neighbouring country, information such as the driver's identity

	and license, his/her track-record, the truck's travel history and cargo inventory can be transferred to the border authorities to facilitate verification & control. 4. Fusion of available information such as traffic on the road, traffic light status, feeds from street cameras, border control traffic, type of cargo and risk level to determine the trajectory / speed of the truck towards the border (e.g. assigned to specific control lane or crossing based on the type of material transported, or based on risk assessment, etc.) and to enable an increased cooperative environmental awareness. (**2-5 km before the border crossing**). 5. Deployment of extra remote inspection methods in order to acquire additional information about the approaching truck and to verify the received information (eMBB). This could be the deployment of drones, the feed from mounted cameras, thermal or x-ray imaging, weight analysis of the truck, etc. (**0-2 km before the border crossing**). i. The feed from the cameras / drones can optionally be transmitted over 5G networks to the neighbouring country authorities to prepare them for the arrival of the truck and for cross-checking purposes. 6. Based on data fusion originating from the truck, environmental sensors and cameras and wearables / smart phones that the customs agents are equipped with, the integrated assisted driving platform hosted at the edge server provides live updates of the maps to the navigation software of the truck, depicting the live location of the other road users and potentially additional information. i. Increased cooperative environmental awareness is achieved for the truck, identifying all road users and border ground personnel (even in blind spots) ii. Increased safety for the ground personnel in case of a predicted accident with an incoming truck. The Predictive analytics platform may issue a warning or order to the truck's OBU to brake or slow down (trajectory alignment is also possible) as well as warn the ground personnel about the imminent danger. 7. Final data fusion including all acquired information to perform predictive analytics and risk level assessment of the specific

	truck and to classify it according to the level of verification that was possible. i. If all data checks out, then the truck will be potentially capable of going through the border without human intervention ("zero touch" scenario). ii. If there are uncertainties, then different levels of risk assessment or doubt will trigger differentiated treatment by the border officers, according to the predicted level of risk. 8. Human intervention at the actual border crossing will depend on whether the gathered information was verified and on the assessment of the risk level for each truck.
Post conditions	• A truck that has successfully passed all remote inspection methods crosses the border without human intervention • Border inspection is categorized and prioritized based on risk assessment • Border inspections become more efficient and less time consuming • Border ground personnel is protected from potential accidents • Increased cooperative awareness of the surrounding, making more advanced CCAM scenarios possible.

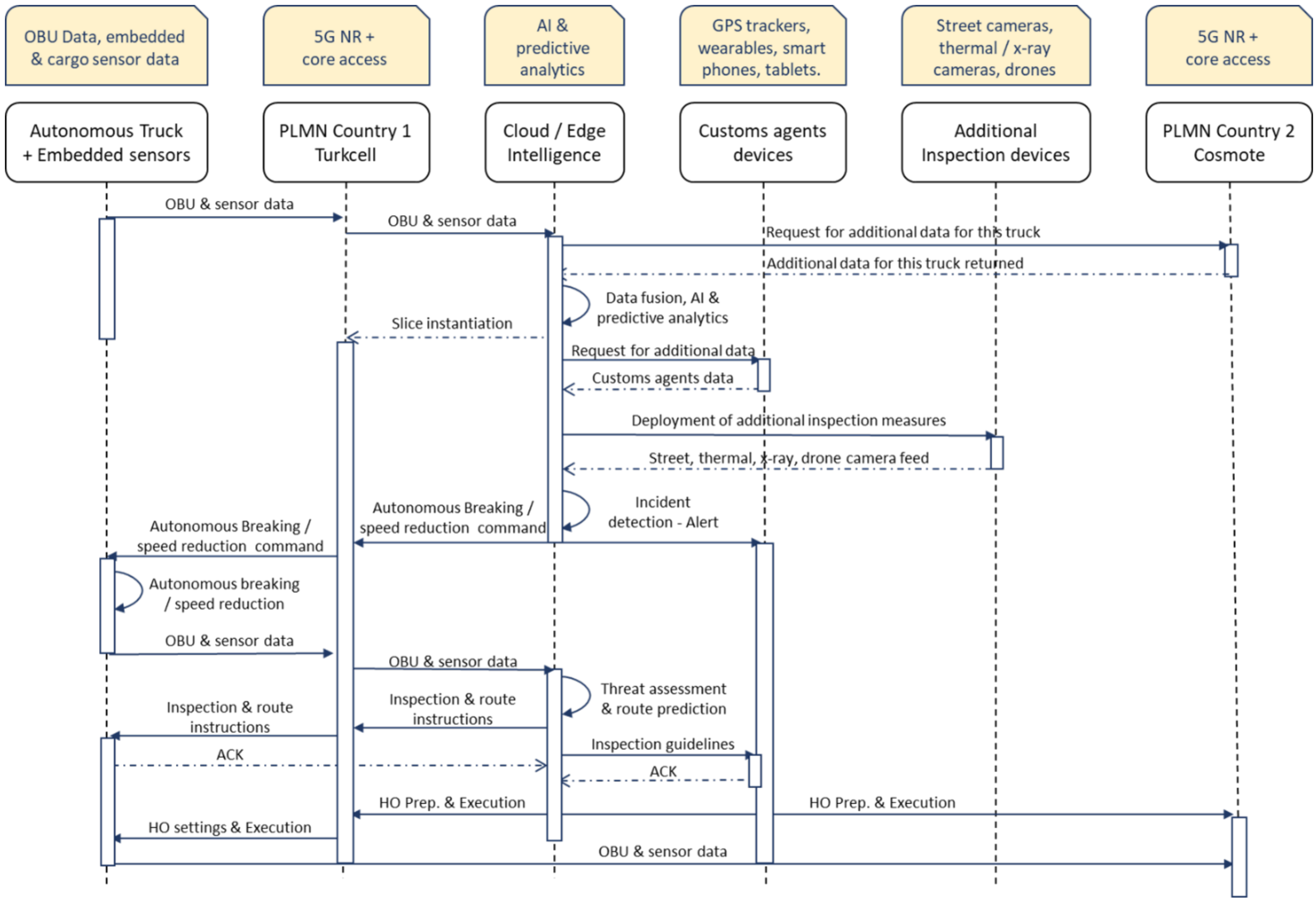

Figure 72 Assisted border crossing sequence diagram

14.3.1.3. Beyond state of the art

The use of 5G networks in combination with advanced CCAM functionality can significantly contribute to the mitigation of the border control delays by providing customs agents with advanced functionalities which enable inspection preparation, enhanced flow of information and instant status verification and which can under the right circumstances realize a "zero-touch" border crossing. Moreover, the increased ultra-reliable and low latency gathering of information from various sources around the border-crossing can increase the cooperative environmental awareness through "live maps" and even actively assist in the protection of the customs agents and police officers offering immediate and reliable feedback to the vehicles and enabling automated driving reactions.

14.3.1.4. *5G services*

Table 75 Overview of 5G services to be implemented in the Assisted border crossing user story

5G service	Implementation
eMBB	Yes. eMBB slices will be used in this user story for the transmission of 4K video from street cameras and deployed drones as additional inspection measures.
URLLC	Yes. uRLLC slices will be used for the transmission of data from the truck sensors to the edge platform and for the communication of CCAM related commands back to the truck (e.g. to brake upon the detection of a collision possibility).

14.3.2. References

[1] "Cellular Vehicle-to-Everything (C-V2X): Enabling Intelligent Transport," GSMA Whitepaper

[2] 3GPP TR 22.866 : "Study on enhancement of 3GPP Support for 5G V2X Services"

[3] M. Miltiadou, E. Bouhouras, S. Basbas, G. Mintsis and C. Taxiltaris, "Analyis of border crossings in South East Europe and measures for their improvement", Aristotle University of Thessaloniki, Faculty of Rural and Surveying Engineering, WCTR 2016 Sanghai, July 2016

14.3.3. UCC#3, US#2: EDM-enabled extended sensors with surround view generation (DE)

14.3.3.1. *Motivation*

Cooperative perception represents an important technology for automated vehicles. Traditional four (front, left, right, rear) camera based individual detections might not be sufficient for L4/L5 automation, posing the risk that the field of view can be blocked by the car's surroundings (vehicles, buildings, etc.). Even if there are no obstacles, the field of view obtained by the on-board sensors can be compromised due to blind spots, weather conditions (direct sunlight, heavy rain, etc) or other environmental factors. A cooperative perception functionality that continuously updates a Local Dynamic Map (LDM) representing the real world by fusing on-board sensor data with the data of other traffic participants and HD maps is proposed in this user story. Using current communication technologies, the bandwidth is not enough to support the exchange of for example video raw data between vehicles. While it could be sufficient for some ADAS application to share only pre-processed sensor data (objects) today's network latencies pose a risk to potentially safety relevant functions. Still, sharing pre-processed data is not enough if it should be visualized to the driver to support manoeuvre planning, for instance, during vehicle handover from L4 automation to manual human driving, when the vehicle drives out of its operational design domain (ODD), thus, the specific conditions under which the driving automation system was designed to function. The proposed cooperative perception technology generates a surround view to support the driver in "building" his/her situational awareness according to the current driving context, and then to help him/her to take the control of the car in an appropriate way, in order to manually manage the situational risk and/or to safely perform the driving task. The enhanced surround view can also be provided to the driver or the passengers to keep them in the loop while the car is doing something that can be considered risky like a lane change or an overtake. This way they can be calm and feel safe, knowing that the autonomous vehicle is taking the right action. Consequently, their user experience will be increased.

14.3.3.2. Description

Table 76 Overview EDM-enabled extended sensors with surround view generation user story

Use Case Category	Extended sensors
User Story Leader	Valeo
Other partners	Vicomtech, TUB
Objective	Exchange and fusion of sensor data from different vehicles for safe and user-friendly automated and cooperative driving.
Actors	Vehicle A, Vehicle B, Vehicle C, eRSU 1, eRSU 2
Pre-conditions	• Vehicle A, B and C support 5G connectivity • Vehicle A, B, and C equipped with sensors (cameras, lidar, GPS, odometry, etc.) • At least Vehicle B and C have computing capabilities for advanced sensor fusion and HD maps. • Vehicles A, B and C are driving on the same lane one after the other. Vehicle A goes on the front, then Vehicle B and finally Vehicle C on the rear. The three vehicles are sharing messages with common data exchange format with their corresponding eRSU. This information would include the ego vehicle position, speed, heading, its planned trajectory and other relevant LDM data. eRSU1 and eRSU2 synchronise their EDMs
User Story flow	1. Vehicle A finds the lane blocked as the front vehicle has suddenly stopped. 2. Vehicle A brakes and starts a lane changing manoeuvre. 3. The brake is propagated (Vehicle B reduces its speed because Vehicle A has done it and then Vehicle C reduces its speed as

	Vehicle B has done it), keeping the safety distance between vehicles. 4. Vehicles B and C have their field of view restricted, so they request the EDM to eRSU1 to enhance their LDM, understand current situation and plan next manoeuvre. 5. eRSU 1 sends EDM to Vehicles B. and C. 6. Vehicles B and C fuse the received EDM with their LDMs and HD maps. 7. Vehicle C determines that it needs raw sensor data from Vehicles A and B. 8. Vehicle C requests perception sensor raw data from Vehicle A and Vehicle B 9. Vehicle A sends data from its sensors to Vehicle C. 10. Vehicle B sends data from its sensors to Vehicle C. 11. Fusion module in vehicle C generates a 360º surround view using its own sensor data, the sensor data from Vehicles A and B, the LDM, the EDM and HD maps. 12. The surround view is used for a safe lane changing and overtaking manoeuvre of Vehicle C, keeping the passengers in the loop. Vehicles A and B have a less obstructed view and find the EDM+LDM information enough for the lane change.
Post conditions	Vehicle A, Vehicle B and Vehicle C have successfully changed lane and overtake the obstacle. Due to the dramatic limitation of Vehicle C's field of view, during the manoeuvre, enhanced surround view is provided in Vehicle C to the driver and passengers to keep them in the loop and improve manoeuvre planning and safety.

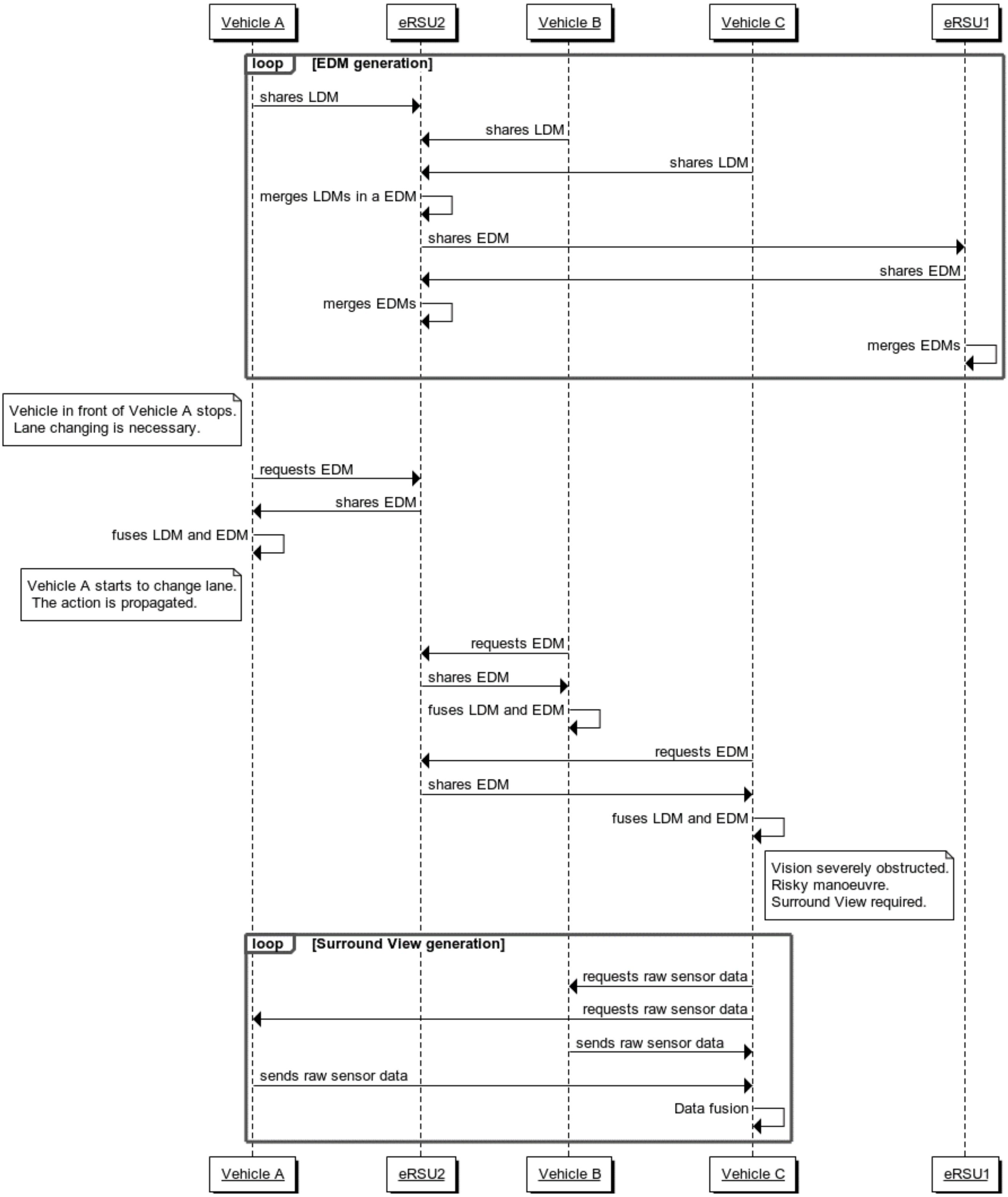

Figure 73 Sequence diagram for EDM-enabled extended sensors with surround view generation user story

14.3.3.3. *Beyond state of the art*

Current L3 Autonomous Driving vehicles only depend on on-board sensors. The technology deployed in this user story exploits also the sensor data received from other vehicles, thus mitigating the limitations faced by using solely on-board sensors and enabling L4 Autonomous Driving.

One of the main novelties that the user stories proposes is the concept of providing the driver and the passengers with a 360º surround view to keep them in the loop.

14.3.3.4. *5G services*

Table 77 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes, the different data flows provided by infrastructures and vehicles and consumed by vehicles would produce a big amount of High-Quality video streams being rapidly published, subscribed and consumed.
URLLC	Yes. uRLLC slices will be used for data sharing between the vehicles and the eRSU.

14.3.4. UCC#3, US#3: Extended sensors with redundant edge processing (FI)

14.3.4.1. *Motivation*

Automated vehicles with cooperative perception functionalities obtain distant information by exchanging data. Some benefits include [S. Kim et al., "*Cooperative perception for autonomous vehicle control on the road: Motivation and experimental results*," IEEE Int. Conf. Intell. Robots Syst., 2013]:

- the sensing area can be extended to the boundary of automated vehicles
- the prices of sensors and radio devices are affordable
- beyond line-of-sight sensing is possible depending on the network connectivity
- traffic flow and safety are improved.

From computing perspective, automated vehicles are supposed to be able to locally handle most data processing tasks, such as real-time lane detection and tracking. However, external computing resources are still needed to support cooperation between automated vehicles and with infrastructures. For example, higher SAE automation levels (L4/L5) inherently demand higher levels of independence hence of situational awareness, which requires cooperative perception based on data from multiple sources including different vehicles and infrastructures. To shorten response delay and to avoid moving tremendous data from the automated vehicle through core network, it is essential to move computational resources closer to where the data is generated. In practice, data can be gathered and processed at edge computing nodes located in wireless access networks. Similar with network connectivity, automated vehicles are expected to connect to at least two edge nodes at the same time to improve reliability and performance through parallel data processing.

Currently automated vehicles are typically attached to a single network. This not only impacts service availability due to lack of fall-back options when connection outage occurs, it also may limit interaction between vehicles and/or roadside infrastructure elements that are connected to different networks. From computing perspective, most computing tasks are handled by automated vehicles or sent to remote cloud for processing. Edge computing services required by higher SAE automation levels have not been well studied.

5G provides ultra-low latency and edge computing capacity which are required by automated driving but not available in 4G networks. The multi-PLMN arrangement may constitute the automated vehicle attachment to a number of possible network combinations. In addition to benefits of improved reliability of connectivity but also provides the opportunity to automated vehicles connected to a home network in a particular location to access enhanced V2X services from a visited network with 5G coverage in that location.

14.3.4.2. Detailed description

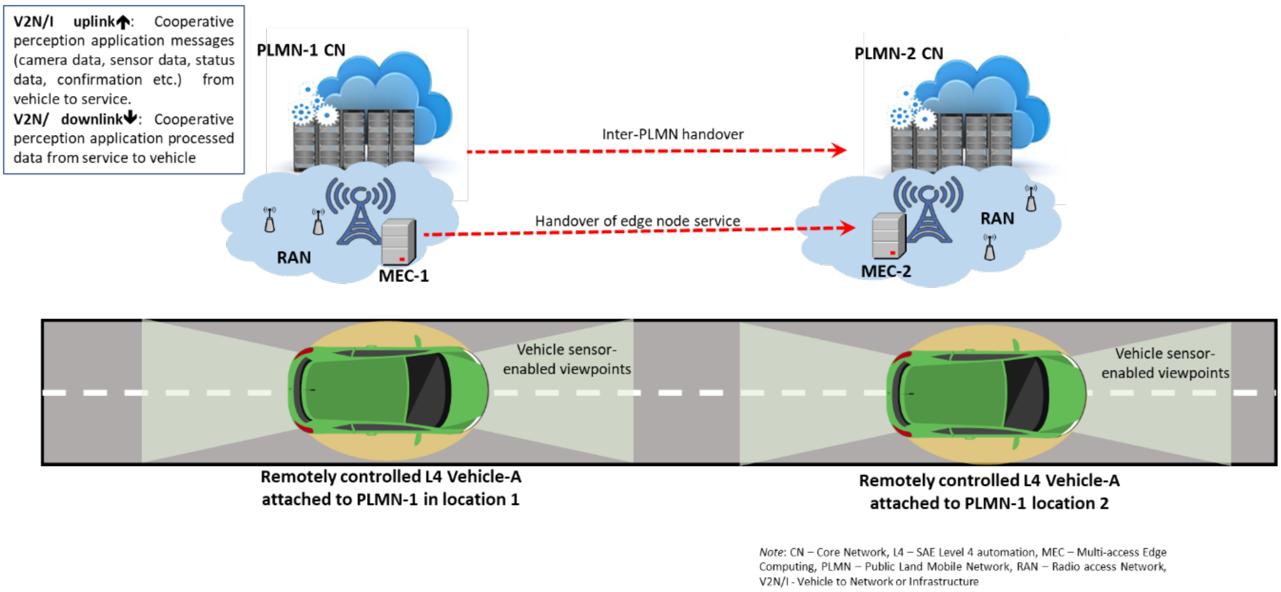

Figure 74 Extended sensors with redundant edge processing

Table 78 Overview of Cooperative perception user story

Use Case Category	Extended sensors
User Story Leader	AALTO
Other partners	SENSIBLE4, VEDECOM
Objective	To increase the safety and independence of automated vehicles.
Actors	Automated vehicle, home PLMN operator, visited PLMN operator(s), Edge nodes
Pre-conditions	Automated vehicle is able to attach to/roam between all PLMNs/MECs considered in the multi-PLMN/MEC scenario
User Story flow	1. Automated vehicle starts journey with separate V2N connections to both PLMN1 / MEC1 and PLMN2 / MEC2 2. A V2X application run by the automated vehicle selects V2N with best QoS 3. - The V2X application run by the automated vehicle swaps the V2N connection when QoS of current connection drops below secondary V2N connection
Post conditions	Vehicle has received updated perception from edge computing service

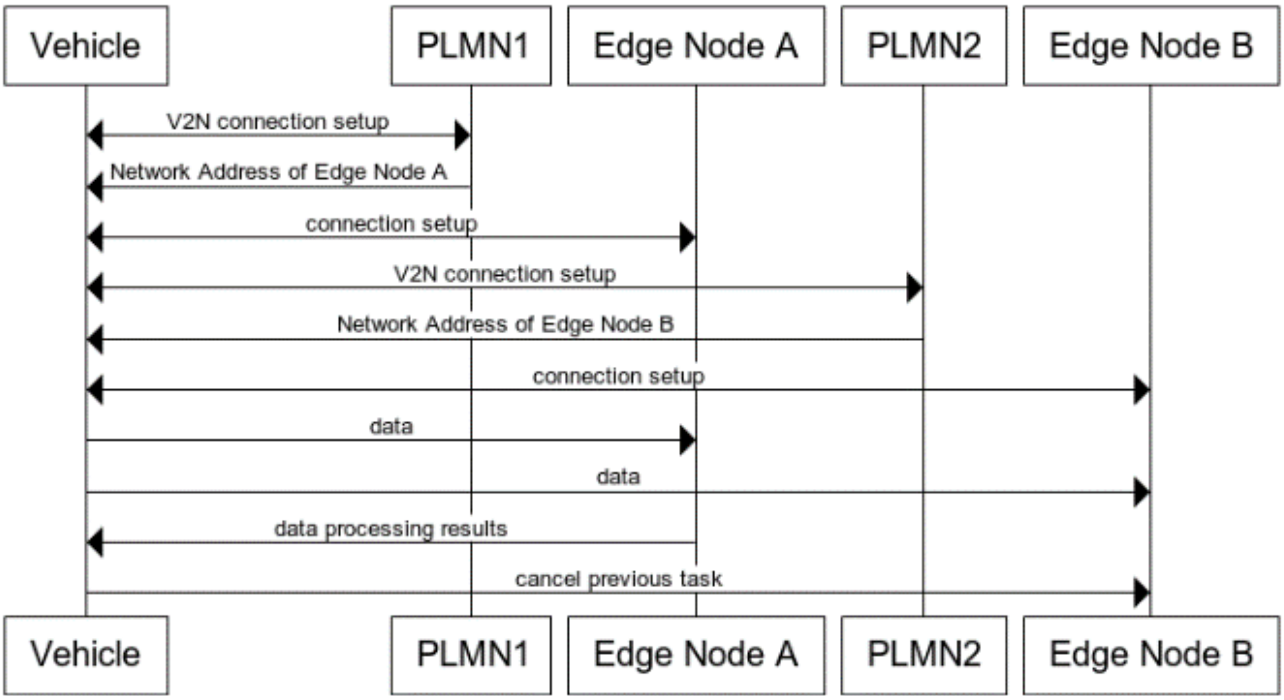

Figure 75 PLMN/MEC migration sequence diagram

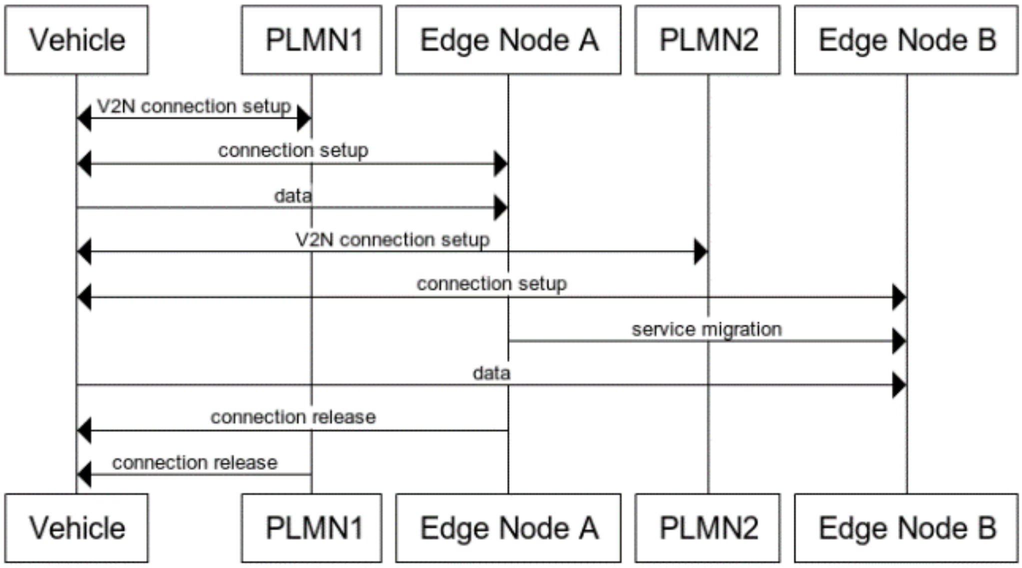

Figure 76 PLMN/MEC migration sequence diagram

14.3.4.3. Beyond state of the art

Based on the 5GCAR project, the availability of computing capabilities at the edge of the network, is critical to support [automated] vehicles user stories. Specifically, when an [automated] vehicle is predicted to hand over from a base station connected to one MEC server to a new base station connected to a different MEC server, the pending jobs are pre-emptively transferred to the new one, with the purpose of minimizing any job interruption caused by the handover. The introduction of these 5G-based V2X applications, particularly those with URLLC service demands, creates then a need for the reliability and latency impact on a V2I connection to be minimal when the automated vehicle roams from one edge node to another (in both national roaming and cross-border scenarios). Furthermore, there is need to evaluate how V2X applications will benefit by the V2I connections having the redundancy of being attached simultaneously to two or more edge nodes. This includes scenarios whereby the data from the automated vehicle is processed simultaneously through multiple edge nodes or when the connection for the processing task is switched form one edge node to another (in a typical national or international roaming scenario). This 5G-MOBIX use-case provides an opportunity to study the new possibilities and challenges offered by edge nodes architecture in the context of V2I for automated vehicles.

Additional experimentation at AALTO will leverage the ARF software-defined radio platform to study the challenges and new possibilities offered by cloud-RAN architecture in the context of V2I. In this 5G-based cell-free architecture, multiple multi-antenna RSUs are controlled by a common gNB. The cell-free architecture allows for implementation of mobility management solutions for seamless handover of a V2I connection from one RSU to another as the vehicle traverses the road. Furthermore, the ARF software-based implementation allows for cellular/application co-deployment on edge computing infrastructure by placing a mobile edge-cloud instance alongside the ARF gNB controller to provide low-latency decision-making capability.

14.3.4.4. 5G services

Table 79 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes, HD video uptake from automated vehicles and infrastructure to PLMN/MEC.
URLLC	Yes, HD video processing in the PLMN/MEC to automated vehicles and infrastructure.
Other	No

14.3.5. UCC#3, US#4: Extended sensors with CPM messages (NL)

14.3.5.1. Motivation

In this user story, highlighting the theme of international travel, we consider automated driving (AD)/connected vehicles in the motorway A270/N270 connecting the cities of Eindhoven and Helmond in the Netherlands. The ego vehicle starts from the Automotive campus and drives autonomously towards the Technical University of Eindhoven campus, successively crossing borders of different 5G networks (i.e. multi-Public Land Mobile Network (PLMN) provided by three partners (KPN, TNO, TU/e). Collective perception of environment (CPE) is an important technology for AD. Traditionally, a vehicle makes use of on-board sensors to create a perception of the environment. However, on-board sensors have their own limitations in terms of field-of-view in addition to the challenges posed by weather conditions, blind spots and far ahead road and traffic conditions. In this use case, vehicles and road side unit (RSU) exchange information in real time to enhance their perception of the environment. CPE can improve the safety of AD vehicles and traffic flow by providing better anticipation, which in turn increases energy efficiency and reduces the carbon footprint. CPE can aid in the coordinated control of vehicles as in cooperative collision avoidance or cooperative manoeuvre such as lane change, merge and diverge. By connecting to existing C-ITS and traffic management road-side information systems, and by exploiting sources from legacy traffic that are available in the cellular network, it can further improve the traffic flow. 5G technologies play the crucial role of enabling the exchange of high frequent messages (e.g., Collective Perception Message (CPM)) and high-resolution perception data such as camera, LIDAR, occupancy grid and/or detailed planned trajectory in real-time, which requires high bandwidth and low latency communication.

14.3.5.2. Detailed description

In the NL trial, CPE will be evaluated in a cooperative merging scenario as shown in the figure below:

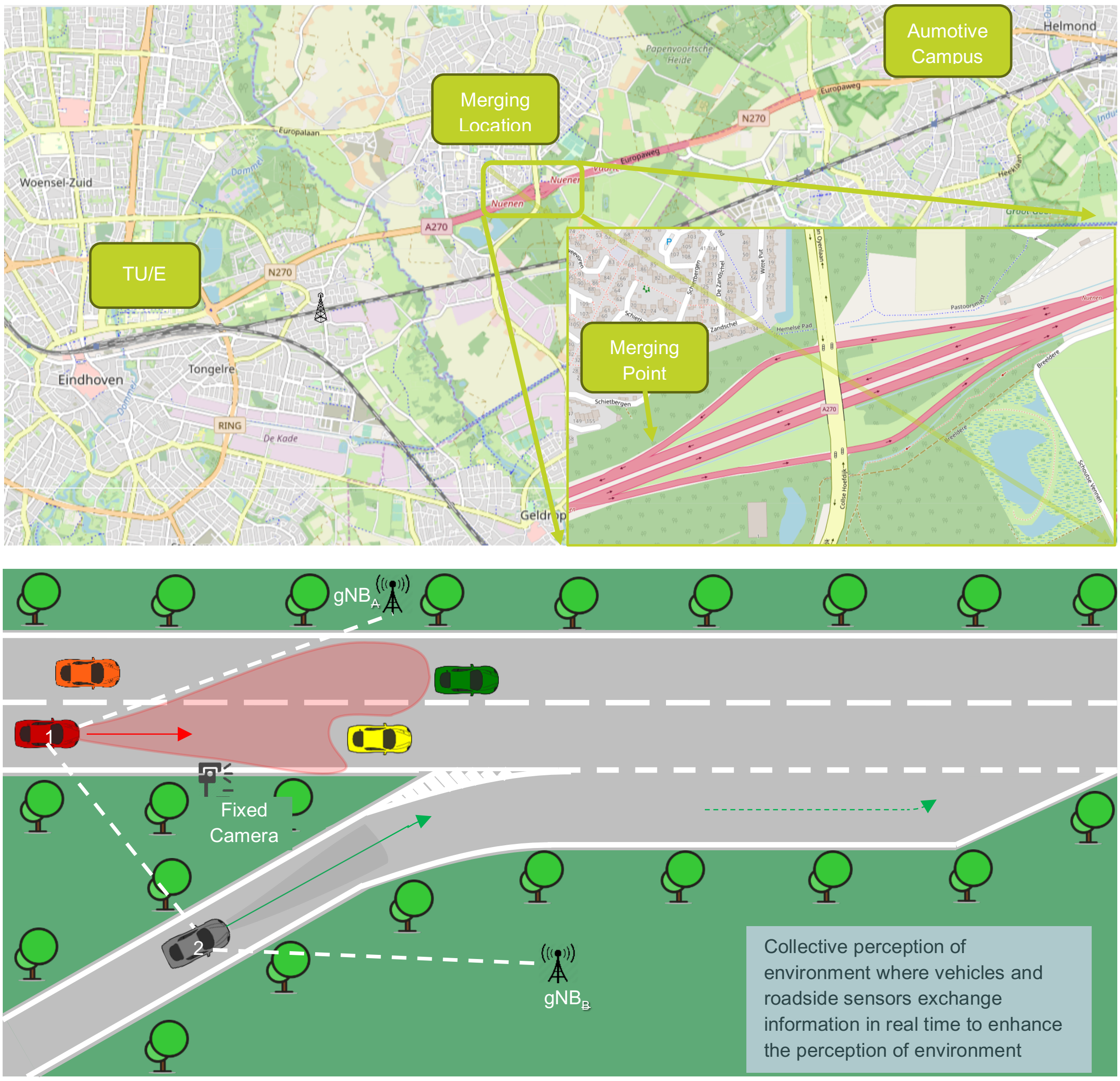

Figure 77 Collective Perception of Environment in cooperative merging example

Table 80 Extended sensors with CPM messages

Use Case Category	Extended sensors
User Story Leader	TNO
Other partners	SISSBV, KPN

Objective	Collective perception of environment where vehicles, roadside sensors and gNodeB exchange information in real time to enhance the perception of environment
Actors	AD_Vehicle_1, AD_Vehicle_2, roadside cameras, gNodeBs, 5G operators
Pre-conditions	• AD_Vehicle_1 and AD_Vehicle_2 are equipped with sensors (cameras, lidar, GNSS, odometry, etc.) • AD_Vehicle_1 and AD_Vehicle_2 are equipped with C-V2X and high bandwidth 5G communication
User Story flow	1. AD_Vehicle_1 is driving on A270 and arriving close to the on-ramp from Nuenen and AD_Vehicle_2 is driving from Neunen and arriving close to the on-ramp to finally merge on to A270; but they cannot see each other due to the restricted field of view of the sensors. 2. AD_Vehicle_1 and AD_Vehicle_2 send request to their respective gNodeBs to extend their field of view. 3. Collective Perception Service aggregates CPMs from vehicles and roadside sensors 4. gNodeBs fetch aggregated CPMs from Collective Perception Service and send them to AD_Vehicle_1 and AD_Vehicle_2 5. AD_Vehicle_2 determines the traffic situation of A270 and checks the merging possibilities considering safety and traffic flow. 6. AD_Vehicle_1 and AD_Vehicle_2 when in range exchange CPM messages over C-V2V. 7. If necessary, AD_Vehicle_1 and AD_Vehicle_2 exchange sensor data (e.g. HD video). 8. AD_Vehicle_2 is on the on-ramp and sends its decision to merge to AD_Vehicle_1. 9. CPE is used for safe and efficient lane merging and finally AD_Vehicle_2 successfully merges on the A270 with AD_Vehicle_1.
Post conditions	• AD_Vehicle_2 merges successfully on the A270 with AD_Vehicle_1. Due to limitation of AD_Vehicle_2's field of view during the merging, enhanced perception of environment is provided for a safe and efficient merging.

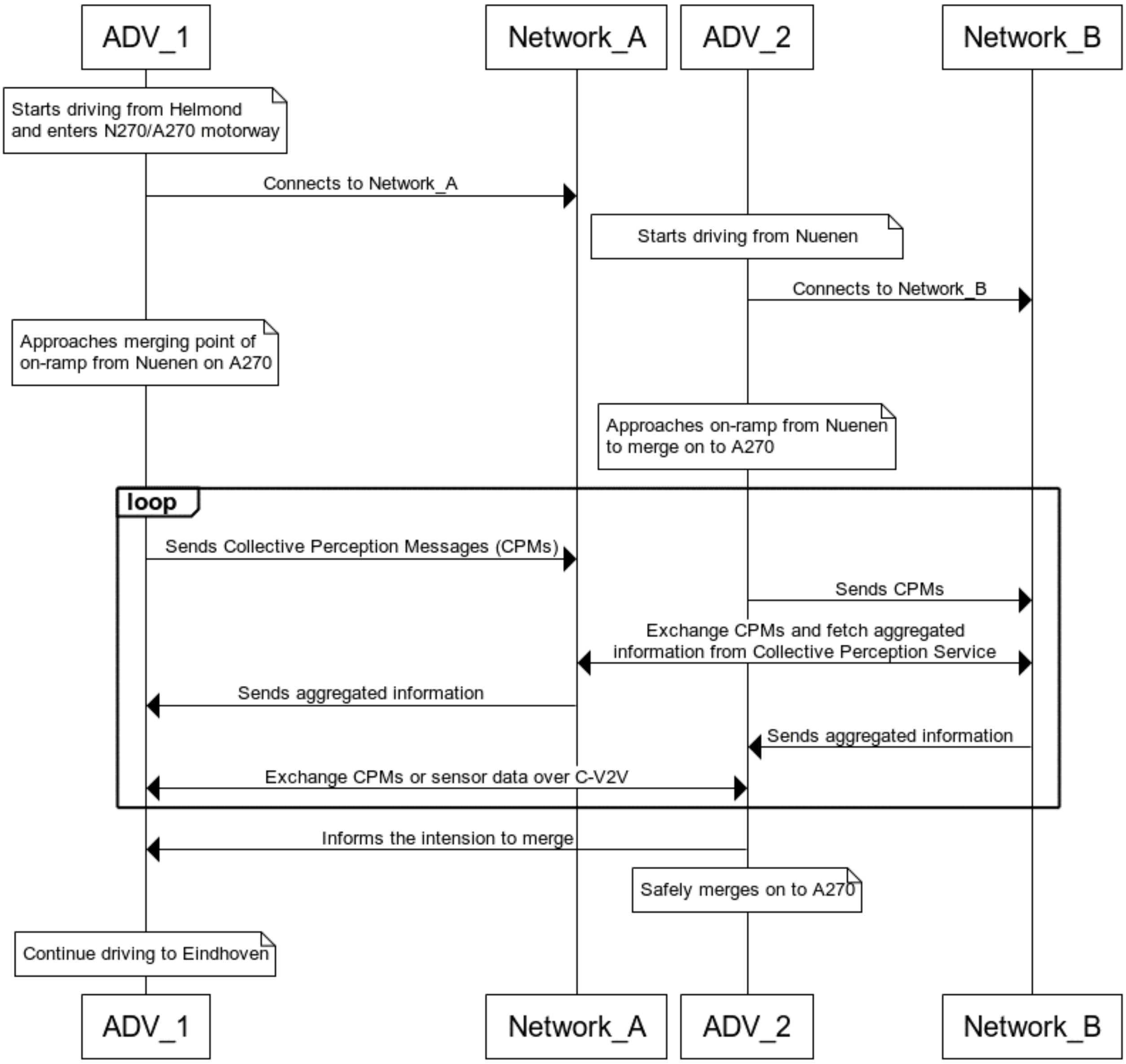

Figure 78 Sequence diagram - Extended sensors with CPM messages

14.3.5.3. Beyond state of the art

The current AD vehicle capabilities are limited by the field of view of the on-board sensors and not so promising communication technologies for safety critical situations. The CPE technology in this user story extends the field of view of a merging vehicle thus provide better options in decision making for a safe and efficient merging. To complement CPE the 5G network capabilities such as high bandwidth, reliable and low latency communication are exploited.

- MEC will be used to orchestrate the communications, applications and functionalities of CPE.
- URLLC will be targeted for low latency V2X data exchange.
- eMBB will be used for high bandwidth communications such as raw data sharing and CPM.

14.3.5.4. *5G services*

Table 81 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes, in CPE for CPM or raw sensors data exchange (e.g. HD video sharing)
URLLC	Yes, for safety critical message exchange of CPE
Other	Inter-PMLN operation with use of MEC and slicing concepts

14.4. UCC#4: Remote Driving

14.4.1. UCC#4, US#1: Automated shuttle remote driving across borders (ES-PT)

14.4.1.1. *Motivation*

Last mile EV Automated shuttle vehicles will play an important role in the near future of European cities. The cooperation of these vehicles with VRUs (Vulnerable Road User) in order to increase comfortability and safety of these users, as well as the fact of having an alternative solution when the path of these vehicles becomes obstructed, suppose a valuable advance in connected cities. 5G technology will enable these developments even in cross-border areas or close to country boundaries.

14.4.1.2. *Description*

Table 82 Overview of Automated shuttle remote driving across borders user story

Use Case Category	Advanced Driving
User Story Leader	CTAG
Other partners	DGT, Nokia Bell Labs, Vigo Council, Telefonica I+D, AEVAC, UMU, Dekra, Vigo, CCG, NOKIA PT, NOS, INFRAPT, IT, ISEL, SIEMENS, A-TO-B, NORTE, TIS and IMT
Objective	To adapt EV Autonomous shuttle behaviour according to specific needs
Actors Scenario 1	• EV Autonomous Shuttle. • Vulnerable Road User (VRU).

Pre-conditions Scenario 1	• EV Autonomous Shuttle shall be equipped with a communication unit connected to the 5G Network, and able to receive cooperative information. • A vulnerable road user (VRU) shall be equipped with a connected device (like a smartphone, wearables or communication units in VRU's vehicles) in order to share its position, speed and characteristics (mobility, vulnerability, etc.).
User Story flow Scenario 1	1. The EV Autonomous Shuttle is driving following a predefined route. 2. The vulnerable road user (VRU) is sharing its position and speed through the connected device. 3. The vulnerable road user (VRU) is moving towards the EV Autonomous Shuttle route, and they will cross. 4. The EV autonomous shuttle receives the information shared by the vulnerable road user (VRU) and analyses it in order to check if they will cross. 5. The EV autonomous shuttle reduces its speed until it brakes, in order to prioritise the vulnerable road user.
Post conditions Scenario 1	5G Networks allows the detection of VRU by the EV Autonomous Shuttle
Actors Scenario 2	• EV Autonomous Shuttle. • Control Centre. • Operator. • Remote Control device.
Pre-conditions Scenario 2	• EV Autonomous Shuttle shall be equipped with a communication unit connected to the 5G Network, and able to receive remote commands coming from the control centre. • The control centre is equipped with a remote control system in order to remotely control the EV autonomous shuttle when needed. • An operator is working in the control centre, monitoring the EV autonomous shuttle and able to use the remote control system.
User Story flow Scenario 2	1. The EV Autonomous Shuttle is driving following a predefined route. 2. While driving, the EV autonomous shuttle detects an obstacle that cannot be avoided following the defined route. 3. EV autonomous shuttle sends an alert to the control centre to inform about the situation.

	4. An operator receives the alert in the control centre and verifies the obstacle using the camera of the remote control system. 5. The operator remotely controls the EV autonomous shuttle, in order to avoid the obstacle and return the vehicle to the predefined path. 6. The EV autonomous shuttle continues the normal route.
Post conditions Scenario 2	5G Networks allows remote control of an EV autonomous shuttle.

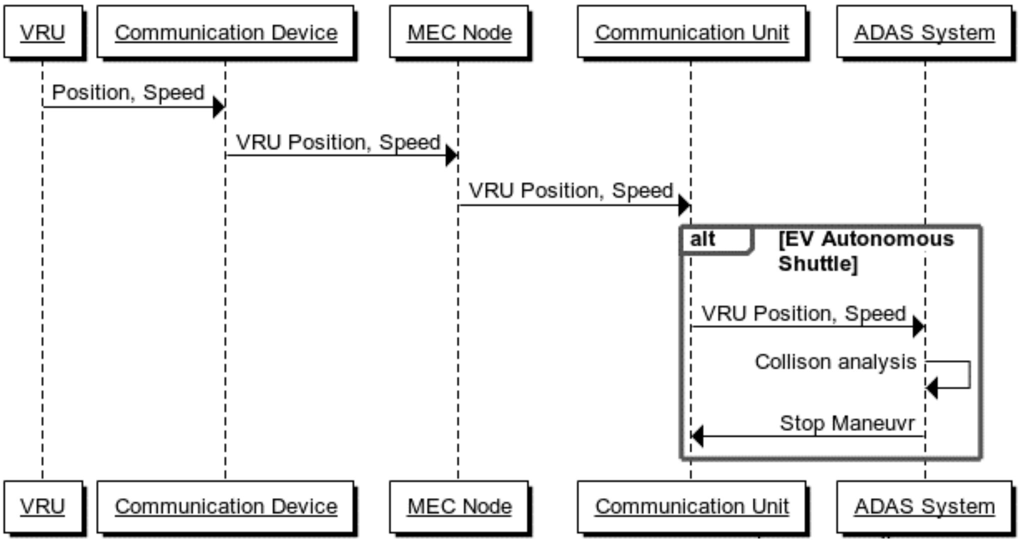

Figure 79 Sequence diagram Scenario 1 Automated shuttle remote driving across borders

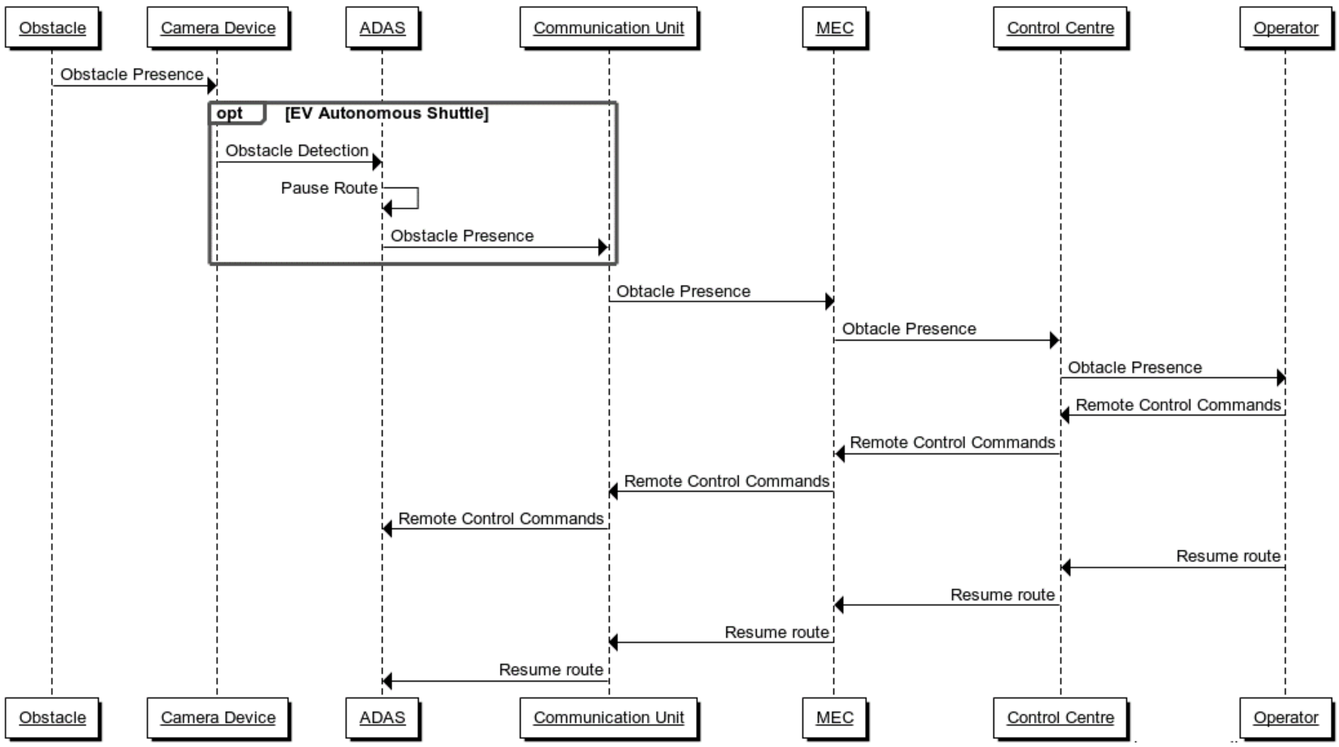

Figure 80 Sequence diagram Scenario 2 Automated shuttle remote driving across borders

14.4.1.3. *Beyond state of the art*

The aim of these User stories is to improve safety and comfortability in last mile autonomous shuttle services and vulnerable road user lives. These advances will be built on 5G technologies that will allow us to immediately communicate different vehicles/VRUs with very low latency, connect a huge number of devices simultaneously, as well as transfer big amounts of data on real-time.

14.4.1.4. *5G services*

Table 83 Overview of 5G services to be implemented in the Last Mile Automated Shuttle user story

5G service	Implementation
eMBB	Yes, High bandwidth capabilities in order to provide a 4K Camera system from the EV autonomous shuttle towards the Control Centre.
URLLC	Yes, Low latency to guarantee camera image is according to the reality of where the EV autonomous shuttle is driving. Low latency to ensure remote command are received in real time.
Network Slicing	Yes, to prioritize remote control commands and camera when the EV autonomous shuttle is being controller by the operator.

14.4.2. UCC#4, US#2: Remote driving in a redundant network environment (FI)

14.4.2.1. Motivation

Remote driving of a high automation (SAE L4) vehicle occurs when the vehicle is remotely controlled, by a human operator, and in some cases a cloud-based application within the domain of a Remote Operations Centre [3GPP TR22.886]. A number of business-, socially- or safety-inspired scenarios may motivate remote driving of L4 autonomous vehicles [5Americas 2018][7]. These include:

- Facilitating cloud-driven autonomous shuttles or public transportation services with predefined routes and stops;
- Providing remote driving services for individuals who are unable or unlicensed to drive (e.g. youth, elderly, disabled persons etc.);
- Providing a fall-back driving solution for autonomous vehicles which have encountered unfamiliar navigation environments or developed some faults;
- Providing a solution for autonomous vehicle fleet owners to remotely-control their assets (e.g. delivering/retrieving rental vehicles to/from customers, moving trucks between different delivery drop-off points etc.)

In a typical remote driving scenario, the remote human operators would utilise live data feeds from vehicular sensors (LIDAR, radar, camera, etc.) to formulate and send back commands for controlling the vehicle in a more reliable manner over a V2N connection between an L4 vehicle and a Remote Operations Centre. The reliability and effectiveness of the commands from a remote human operator of an L4 vehicle is contingent on the quality and timeliness of the data received from the vehicle's sensor feeds. Therefore, any significant constraints or disruptions in the sensor data transfer would not be tolerable in a remote driving scenario. For instance, limits on the uplink throughput in a V2N connection would limit sensor data feeds in terms of achievable resolution, frame (or refresh) rates and compression applied (contributing compression latency). These throughput limits become more severe in road environments with multiple autonomous vehicles contenting the same mobile network resources for V2N communications. The constraints in achievable uplink throughput and area capacity in legacy 4G networks would make wide-scale adoption of the solution challenging.

The increased availability of 5G connectivity will alleviate the aforementioned throughput constraints and reduce latency, as well as, providing additional benefits of security, service discovery and so on. These

[7] 5G Americas white paper, "Cellular V2X Communications Towards 5G", March 2018.

improvements are an enabler higher-resolution sensor data feeds (and possibly more feeds) from vehicle to human operator in Remote Operations Centre.

14.4.2.2. Detailed description

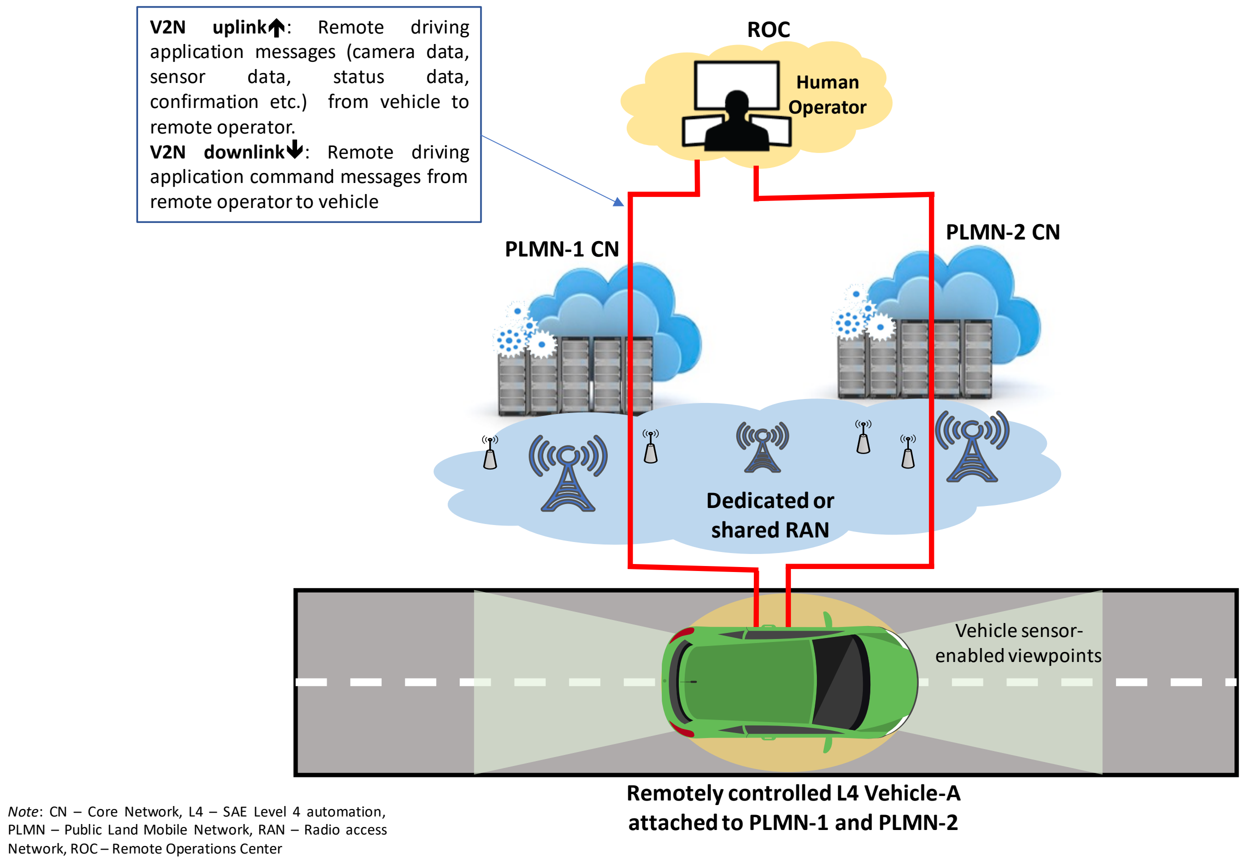

Figure 81 Remote driving in a redundant network environment

Table 84 Remote driving in a redundant network environment

Use Case Category	Remote Driving
User Story Leader	Sensible 4
Other partners	AALTO, VEDECOM
Objective	Human operator leverages remote sensor data feed to control/drive autonomous vehicle.

Actors	L4 Vehicle, Human Operator, Home PLMN operator, Visited PLMN operator, V2X Application Server
Pre-conditions	• Vehicle is equipped with sensors to ensure human operator has acceptable view to execute particular control function • Vehicle supports remote driving application • Vehicle able to attach to all PLMNs considered in the scenario
User Story flow	<u>Scenario 1</u> 1. Vehicle attaches to both PLMN-1 and PLMN-2, with PLMN-1 the primary connection 2. Vehicle triggers request for remote driving operation 3. Vehicle sends sensor data feeds to remote human operator 4. Remote human operator sends command message to Vehicle 5. Vehicle executes control/drive manoeuvre according to command message 6. Vehicle losses connection to PLMN-1 and uses PLMN-2 as primary connection 7. Remote driving data and command exchanges between vehicle and human operator continues via PLMN-2 <u>Scenario 2</u> 1. Vehicle attaches to PLMN-1 2. Vehicle triggers request for remote driving operation 3. Vehicle sends sensor data feeds to remote human operator 4. Remote human operator sends command message to Vehicle 5. Vehicle executes control/drive manoeuvre according to command message 6. Vehicle leaves PLMN-1 coverage area and attaches to PLMN-2 7. Remote driving data and command exchanges between vehicle and human operator continues via PLMN-2
Post conditions	• Remote driving service terminated when no further support or control from remote human operator is needed

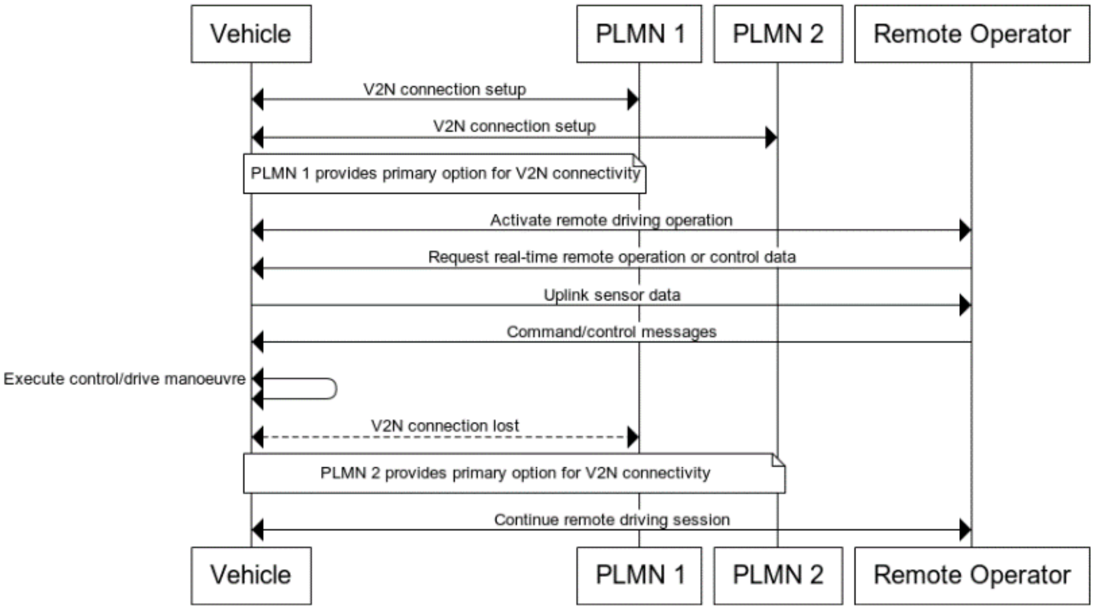

Figure 82 Sequence diagram for Remote driving in a redundant network environment (scenario 1)

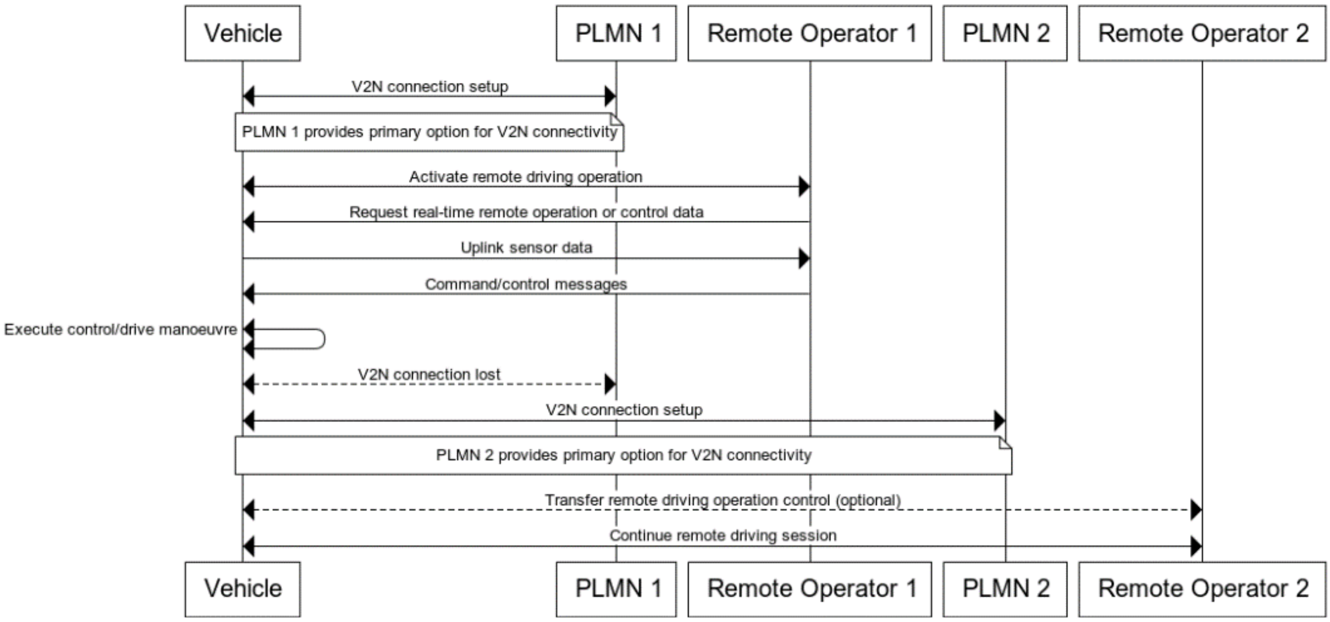

Figure 83 Sequence diagram for Remote driving in a redundant network environment (scenario 2)

14.4.2.3. Beyond state of the art

The continuity of the remote driving sessions within or across multiple PLMN environments creates a number of interesting challenges, particularly environments with different mobile technologies (4G and 5G).

Some of these challenges of maintaining the service in across different systems or operator domains are also highlighted by projects, such as, 5GCAR[8], and the 5G Automotive Association (5GAA)[9]. Different approaches will be explored further in the Espoo trial site to provide further experimental insights on the implementation barriers and potential solutions.

14.4.2.4. *5G services*

5G service	Implementation
eMBB	Yes. Providing high capacity connectivity also in the uplink direction to relax constraints on sensor data feeds.
URLLC	Yes. Reliable and low latency for whole remote driving control loop
Other	No

Table 85: Overview of 5G services to be implemented in the Remote Driving user story

14.4.3. UCC#4, US#3: Remote driving using 5G positioning (NL)

14.4.3.1. *Motivation*

At border crossings on the outline of European Union, manual inspection of automated vehicle is still required even when vehicles become L4 automated. The customs can assign an inspection bay to these L4 automated vehicles and the vehicle should be able to be manoeuvred itself in that spot.

Current similar services (applied in different areas) rely on either fully equipping the vehicle with multiple sensors or using sensors in the infrastructure to locate the vehicle. In both cases, these services are in a controlled environment, with mainly no other traffic involved.

This requires a high level of autonomy and decision making from the L4 vehicle. In the current state of art this is L4 is not yet fully possible, so therefore a simple solution is to have a remote operator take over control in case the vehicle is unable to manoeuvre further (because of i.e. an unexpected roadblock, error in the vehicle system, or because of customs regulations where there is a need for further manual inspection and the vehicle needs to be controlled by the customs).

To manoeuvre a vehicle, sensor data from multiple vehicle sensors (cameras, LIDAR, radar) should stream their information in real time (synchronised and with low latency) to the operator and at the same time have low latency in the control task (manoeuvring the vehicle in real time). Using current communication

[8] 5GCAR Delivarable D4.1, "Initial design of 5G V2X system level architecture and security framework," April 2018 https://5gcar.eu/wp-content/uploads/2018/08/5GCAR_D3.1_v1.0.pdf

[9] 5GAA white paper, "Cellular V2X Conclusions based on Evaluation of Available Architectural Options" March 2019

technologies, the bandwidth is not enough to support the exchange of for example raw video data between vehicles.

5G technology can be aiding in improving bandwidth, latency limitations and reliability for manoeuvring a vehicle automatically into an inspection bay (in a slot assigned by border control remotely/via 5G and local edge computing) as well as using localization (of the car in surroundings by the car, plus potentially of the car by the infrastructure) for monitoring actions of the autonomous car by the border agents.

14.4.3.2. Detailed description

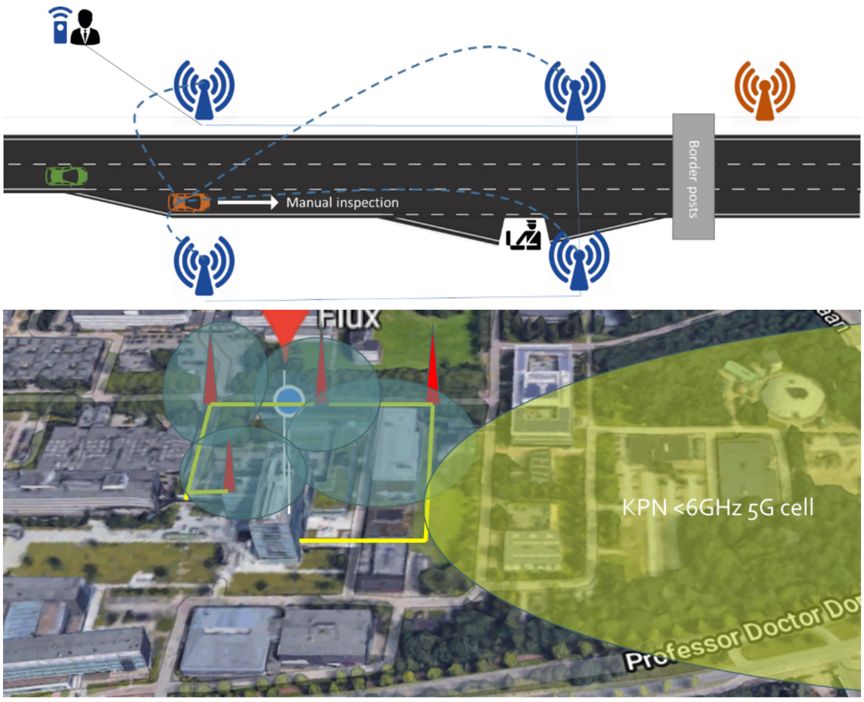

Figure 84 Example of how tele-operation with mm-wave localization (with multiple mm-wave base stations in blue) could be implemented on cross border sites (top) and TU/e site with multiple mm-wave base stations (in red) for testing with adjacent KPN network for handover (bottom).

Table 86 Overview of Remote driving using 5G positioning user story

Use Case Category	Remote driving
User Story Leader	TUE

Other partners	TNO, KPN
Objective	In case of failure of the AD system, remote take over can aid in the manoeuvring of the L4 automated vehicle
Actors	Vehicle (A), Operator (B), Tele-monitoring network (C)
Pre-conditions	• Vehicle is automated driving at L4 (ODD) • Vehicle is not able to continue due to defect, or an unknown road block.
User Story flow	1. Vehicle detects obstacle or error 2. The vehicle requests remote operator intervention 3. The operator analyses the situation and decides to drive the vehicle from the control center. 4. The operator can move the vehicle with a limited maximum speed (because of safety). 5. The operator drives the vehicle to a predefined emergency lane or to the customs inspection bay.
Post conditions	• Vehicle is operational again and operator hands over control to vehicle again • The passenger/driver is informed, or customs are informed to start inspection

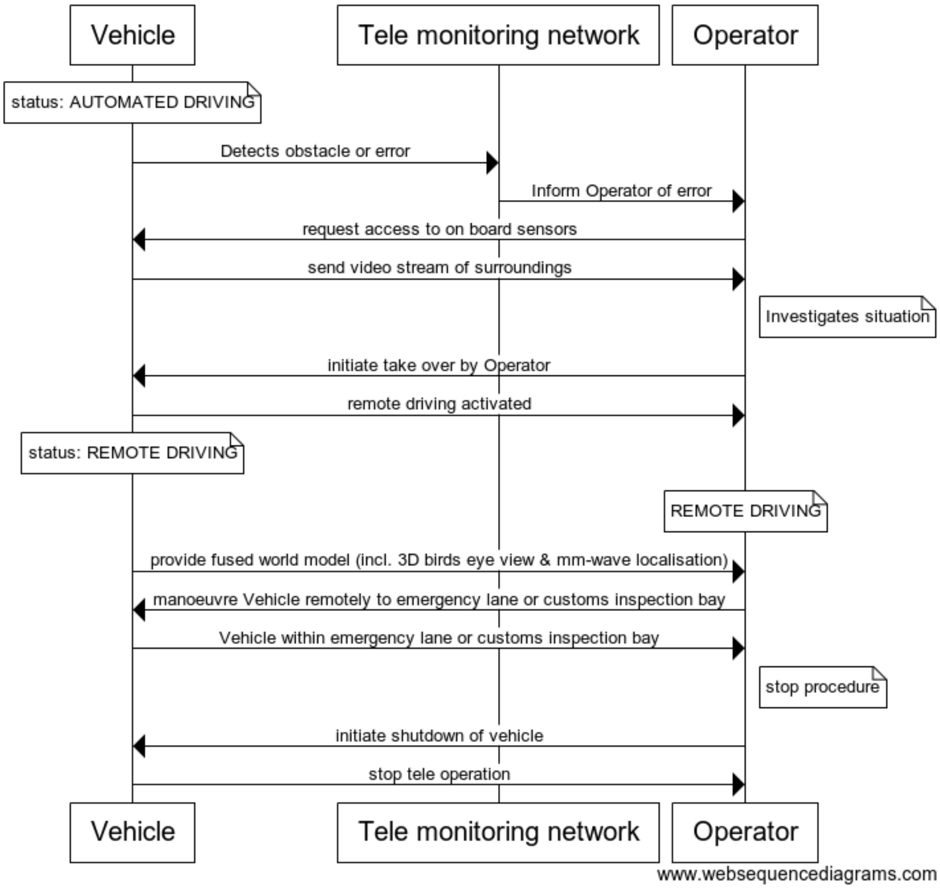

Figure 85 Remote driving using 5G positioning sequence diagram

14.4.3.3. Beyond state of the art

Using 5G technology we aim to:

- Improve localisation of AD vehicle and add redundancy to existing sensor set using 5G mm-wave technology.
- Using the 3D bird's eye view of vehicle sensors with AI enabled by 5G to the operator to perform safe tele-operation.

This technology can also be applied into the collective perception of environment and CoCA user stories of the NL Trial Site.

14.4.3.4. *5G services*

Table 87 Overview of 5G services to be implemented in user story

5G service	Implementation
eMBB	Yes, for sending video streams for remote driving
URLLC	Yes, for precise localization and remote driving

14.4.4. UCC#4, US#4: Remote driving with data ownership focus (CN)

14.4.4.1. *Motivation*

Current V2X technology employs either DSRC or 4G LTE. Both are not the perfect solution to meet the requirements of most V2X scenarios concerning road safety, traffic efficiency, and infotainment.

The 5G network plays an important role in achieving communication between User Equipment (UE), supporting message exchange with ultra-high data throughput and ultra-low latency. Less than 10 ms latency is an important index for regular manoeuvre coordination within the time limit. UEs' message exchange shall be ultra-reliable. 99.99 % reliability for safety coordinated driving manoeuvre.

14.4.4.2. *Detailed description*

Table 88 Overview of Remote driving with data ownership focus user story

Use Case Category	Remote Driving
User Story Leader	DUT(DALIAN)
Other partners	SDIA (SHANDONG), CNHTC, DDET, QILUTIG
Objective	To achieve coordinated driving between autonomous vehicles
Actors	Vehicles A and B, RSU, ME
Pre-conditions	Vehicles A and B support message exchange via 3GPP V2X communication.
User Story flow	1. Control center monitors the status of the autonomous driving Vehicle A 2. Vehicle A sends various states through the RSU and cloud servers 3. Control center receives Vehicle A's information 4. Control center determines whether vehicle A continues to run automatically or the control center takes over it remotely Control center operates Vehicle A remotely.

Postconditions	Vehicles A and B perform the coordinated maneuver.

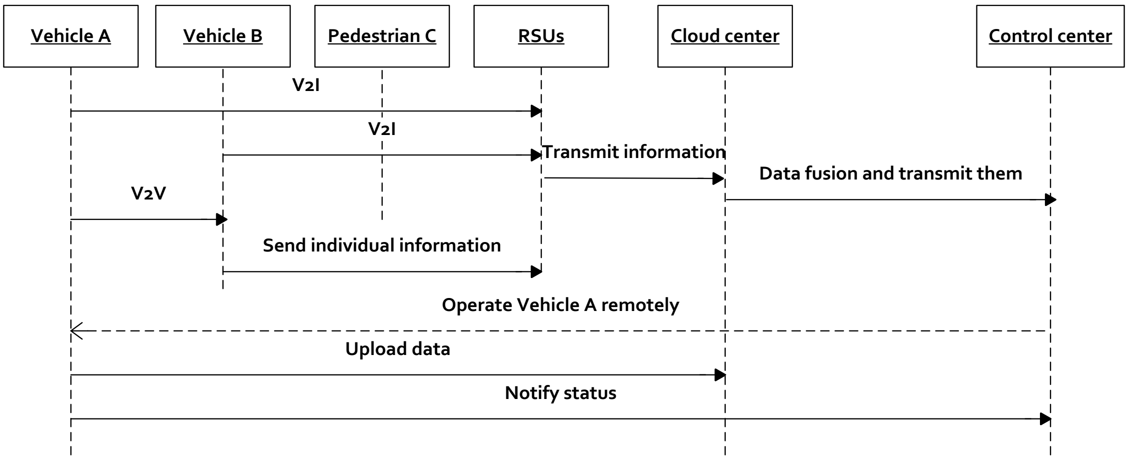

Figure 86 Sequence diagram of Remote driving with data ownership focus

14.4.4.3. *Beyond state of the art*

Our current L3 vehicles employed DSRC V2X solutions. The 5G-MOBIX technology deployed in this user story has long coverage range, ultra-low latency, and ultra-reliable reliability, and will enable L4 Autonomous Driving.

14.4.4.4. *5G services*

Table 89 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes. The remote center can receive HD videos and take control of the vehicles.
URLLC	Yes. The collected data should be delivered by ultra-low latency and high reliable communication in case of emergency.

14.4.5. UCC#4, US#5: Remote driving using mmWave communication (KR)

14.4.5.1. *Motivation*

While automated driving vehicle needs a lot of sensors and algorithms such as obstacle detection and avoidance, remote driving can with human operator should be realized using less of them. A main objective of the remote driving is to control or to driving automated vehicle remotely when the automated vehicle is mal-functioned or driver in the vehicle is in accident such as heart attack. Since the remote driving vehicle is able to share the real time live video stream not only around the vehicle but also inside the vehicle, driver or passengers in the remote-controlled vehicle should be safer during the driving to their final destination.

Technically, remote driving has to be provided multiple up-link video streaming with ultra-low latency and down-link control signal with low latency at the same time. Therefore, 5G key technologies such as eMBB (Enhanced Mobile Broadband), URLLC (Ultra-Reliable Low Latency Communication) should be developed and be validated to realizes this user story.

The challenging aspects are as follows:

- 1Mbps downlink data rate and 200Mbps uplink data rate
- 4k video stream is up to 100 Mbps
- Four live video streams (front, rear, left and right sides) are delivered to a remote driver
- User-plane latency is up to 4 ms

14.4.5.2. Detailed description

Table 90 Overview of Remote driving using mmWave communication user story

Use Case Category	Remote Driving
User Story Leader	KATECH
Other partners	Renault Samsung Motors (RSM), ETRI, SNetICT
Objective	Providing reliable and safe control of the remote driving by high-throughput data sharing between remote driving vehicle and remote site operator
Actors	Remote Driving Vehicle (RDV), Driver, Remote Operator
Pre-conditions	Vehicle is parked or stopped on the road with stable 5G-connectivity to remote site
User Story flow	1. The driver in the remote driving vehicle (RDV) requests a remote operation to the remote operator. 2. The remote operator checks the status of the RDV (speed, video, state of fuel, automated vehicle controller, and so on) and decide to activate remote driving function from the remote site.

	3. The remote operator starts to control or to drive the RDV with limited speed. 4. The remote operator drives the RDV to a safe area. 5. When the RDV is parked, the remote operator checks status of the RDV.
Post conditions	The RDV is parked in a safe area.

14.4.5.3. *Beyond state of the art*

RDV should be realised by supporting 2 key technologies; real-time high definition live video stream and ultra-low latency. However, the existing cellular systems represented by Long Term Evolution (LTE)/LTE-Advanced (LTE-A) and dedicated private V2X communication systems are not able to offer wireless connectivity to RDV that enables such services since these systems were primarily designed for low-mobility environments. Therefore, in 5G-MOBIX, Korean trial site will contribute to developing a mmWave-band 3GPP 5G NR V2I system focusing on eMBB and URLLC technologies to solve the technical challenges encountered in mmWave-band vehicular communications.

14.4.5.4. *5G services*

Table 91 Overview of 5G services to be implemented in the user story

5G service	Implementation
eMBB	Yes. To provide moving vehicles with a broadband mmWave-band V2I link that allows RDV to share raw sensor data and high definition video steam with remote site
URLLC	Yes. Mission critical data exchange with low latency up and down link access between RDV and remote site.

14.5. UCC#5: Vehicle QoS Support

14.5.1. UCC#5, US#1: Public transport with HD media services and video surveillance (ES-PT)

14.5.1.1. Motivation

There are several motivations to develop this User story:

- 5G capacities enhance user's comfortability and user access to multimedia content.
- Enhanced monitoring capabilities for the transport services by accessing the 4k camera in the vehicle.
- Streaming the information of in vehicle sensors to other vehicles in the area.

14.5.1.2. Description

Table 92 Overview of Public transport with HD media services and video surveillance user story

Use Case Category	Vehicle Quality of Service Support
User Story Leader	CTAG
Other partners	DGT, Nokia Bell Labs, Telefónica I+D, ALSA, UMU, Dekra, CCG, NOKIA PT, NOS, INFRAPT, IT, ISEL, SIEMENS, A-TO-B, NORTE, TIS and IMT
Objective	Monitoring Public transport service and improve user's comfortability
Actors	• Public Transport Bus. • Control Centre. • 4k camera. • In vehicle sensors. • Multimedia devices. • Bus passengers.
Pre-conditions	• A public transport bus shall be equipped with a communication unit with 5G capabilities. • 4K Camera shall be installed in the front side of the vehicle, and it shall be connected to the communication unit. • The bus shall be equipped with sensors to recognize de environment. • Through a multimedia device (to be defined) users shall be able to access to high definition multimedia content.

User Story flow	1. Users (bus passengers) access to multimedia services through a device, and they are able to reproduce high quality content without delay. 2. ALSA Control Centre is able to remotely access to the 4K camera content and visualise in real time outside-bus image where the bus is driving. 3. The bus record and send the in-vehicle sensor data to the ITS Centre in order to update the global map. Vehicles around receive updates of the HD map from the ITS Centre.
Post conditions	• 5G capacities enhance user comfortability and user access to multimedia content. • Enhanced monitoring capabilities regarding outside-bus image for the transport services is added thought a 4K camera. • Improve of safety by using the systems in the bus as remote sensors for other vehicles.

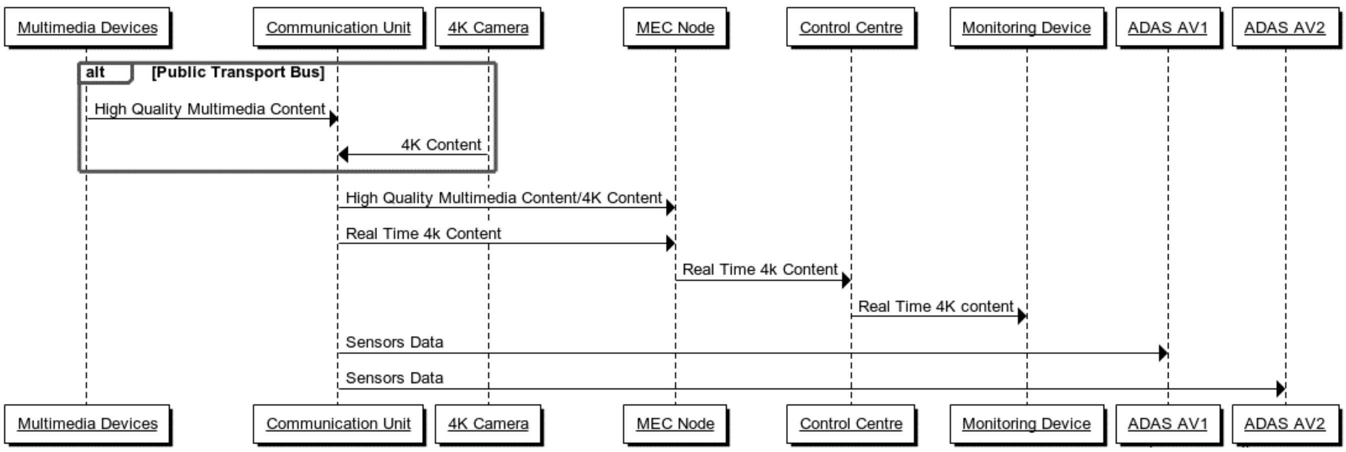

Figure 87 Sequence diagram for Public transport with HD media services and video surveillance

14.5.1.3. Beyond state of the art

This User story aims to take advantage of 5G technologies to improve monitoring systems in a fleet of public transport vehicles, as well as increasing the comfort of the occupants using these vehicles by providing them with high definition multimedia content services. All these goals just become achievable through the capacities of 5G technologies.

14.5.1.4. 5G services

Table 93 Overview of 5G services to be implemented in the user story

5G service	Implementation

eMBB	Yes, High bandwidth capabilities in order to provide a 4K Camera Stream from the Public Bus towards the Control Centre and to allow high quality multimedia services to the bus users.
URLLC	Yes, Low latency to avoid transmission information delay among bus and other actors like control centre and vehicles around.
NR-SA	Yes, connecting directly to the 5G Core allows a best performance for the services of the use case.
C-RAN	Yes, the improvement in network performance provided by C-RAN allows the deployment of the services included in the use case.
Network Slicing	Yes, to prioritize 4K camera quality of service, in case in a concrete area, network coverage is not good enough to provide network to all the bus services.

14.5.2. UCC#5, US#2: QoS adaptation for security check in hybrid V2X environment (FR)

14.5.2.1. Motivation

V2X communications can be used by police authority to detect and localize a suspicious vehicle. The objective is first to identify the vehicle (VIN) and then to give it instructions to stop in a safe area.

In a cross-border context, connected/automated vehicles are in the presence of a hybrid environment of technologies (5G/ Satcom/ 4G). Besides, they can suffer from coverage gap when crossing the border area since there are two different countries' PLMNs and probably different technologies (5G/4G) from each side. As a result, the quality of the link may change which will directly affect the remote-control operation.

A key element in teleoperating vehicles is providing the operator with a sense of presence or awareness of that environment. Traditionally, a video feed is used to provide information to the operator. This video feed, usually from an on-board, front-mounted camera, provides visually rich information of the environment.

Therefore, the biggest challenge in this scenario consists of ensuring the communication continuity between vehicles, infrastructure and the police control centre behind, by adapting the vehicle's transmission parameters (data type, data size, transmission rate, etc) according to the link Quality of Service change.

14.5.2.2. Detailed description

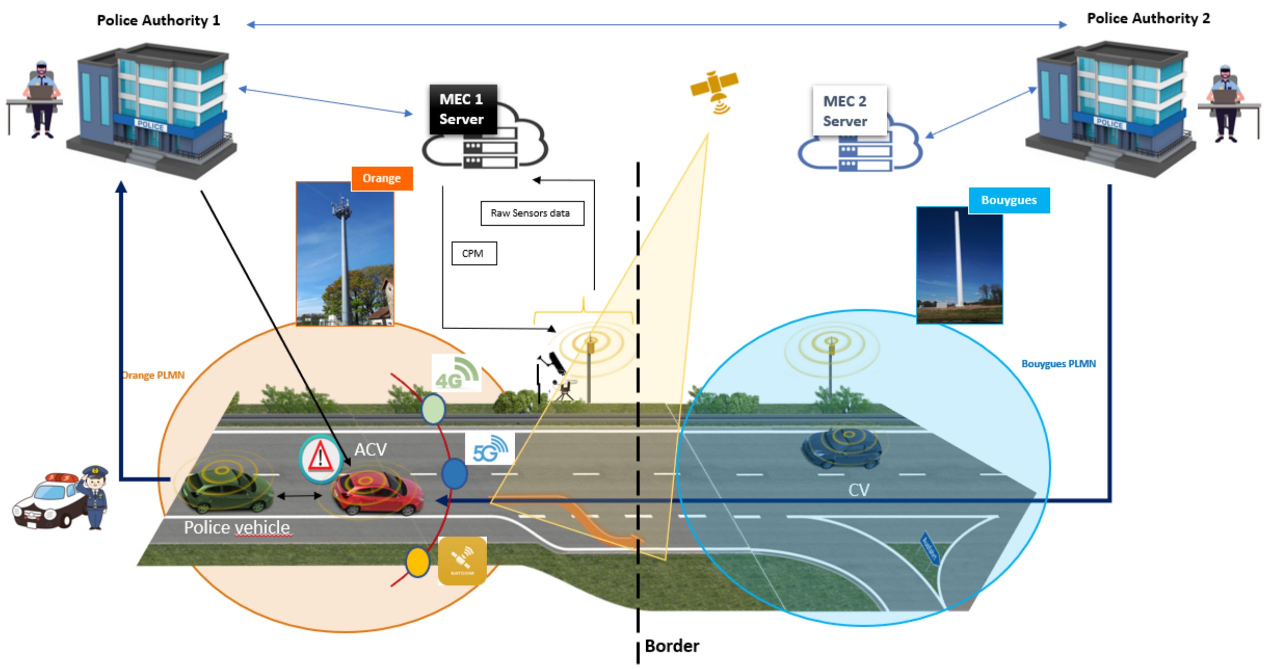

Figure 88 QoS adaptation for Security Check user story

Table 94 Overview of QoS adaptation for security check user story at the French site

Use Case Category	Vehicle Quality of Service Support
User Story Leader	VEDECOM
Other partners	ERICSSON, AKKA, VALEO, Bouygues Telecom, Orange, La Croix, UTAC/CERAM
Objective	Adapt the applications' behaviour based on the quality of service for smoother security check
Actors	Vehicle A, Police car, Police centre 1, Police centre 2, MEC1, MEC2
Pre-conditions	• Vehicle A is an automated and connected vehicle • Police car detects suspicious vehicle A
User Story flow	1. Police car receives V2V CAMs from vehicle A and other vehicles 2. Police car requests Vehicle Identification Number (VIN) and other sensor data (V2V unicast) 3. Vehicle A sends the requested information (V2V unicast)

	4. Police car sends VIN and other information (IP address, target zone) to the police centre (V2C) 5. Police centre 1 asks MEC1 to send sensor data (I2C) 6. Police centre 1 asks vehicle A to send camera video stream 7. Vehicle A starts to stream its camera data to the police centre 1 (V2C) 8. Vehicle A is crossing the border and can suffer from network coverage gap 9. Vehicle A performs soft Handover to the prioritized available network technology according to priority-based network selection algorithm for connection and security check continuity 10. This intelligent algorithm will adjust data type, data size, transmission rate, etc. by taking into account the network and the link quality (5G, Satcom, 4G) 11. Police centre 1 informs police centre 2 about target vehicle crossing the border and request to stop vehicle A 12. MEC1 notifies MEC2 about Handover prediction and MEC host relocation 13. Police centre 2 will request sensor data from MEC2 14. Vehicle A continues sending its camera video stream to MEC2 15. Police centre 2 sends instructions to stop vehicle A to MEC2 16. MEC2 fuses the data received from vehicle A, RSUs and road sensors to calculate the trajectory 17. MEC2 sends MCM message to vehicle A in order to stop 18. Vehicle A stops
Post conditions	• The vehicle is stopped in a safe area and ready for further human security control

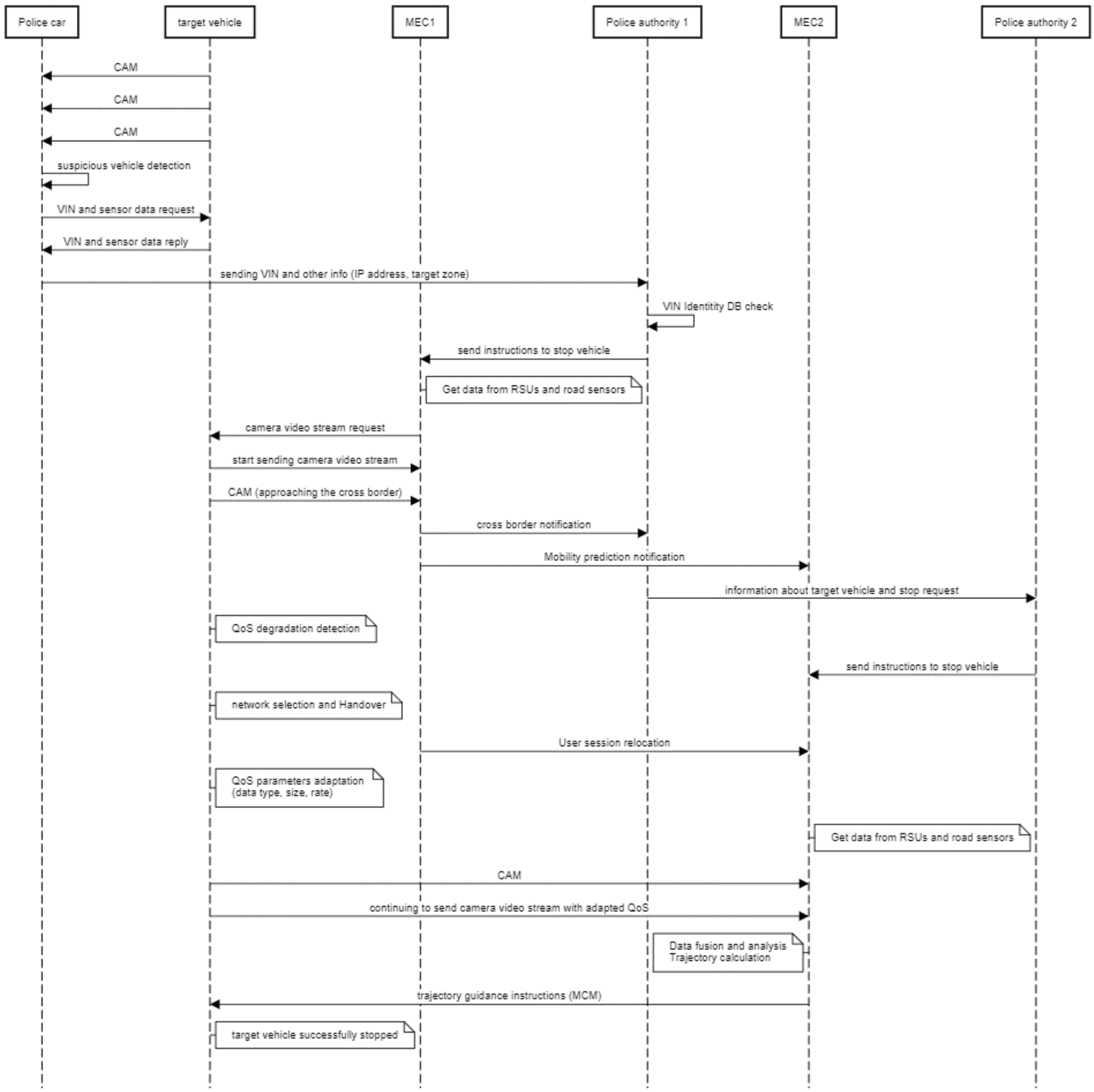

Figure 89: QoS adaptation for security check sequence diagram

14.5.2.3. *Beyond state of the art*

Vehicle quality of service support is one of the most important categories of requirements standardized by 3GPP in order to support V2X scenarios. It enables a V2X application to be timely notified of expected or estimated change of quality of service before actual change occurs and to enable the 3GPP System to modify the quality of service in line with V2X application's quality of service needs. Based on the quality of service information, the V2X application can adapt behaviour to 3GPP System's conditions [1] . ([1] 3GPP TS 22.186 V16.1.0 (2018-12)

One of the benefits of this user story group is to provide a smoother user experience of service especially for safety critical applications.

14.5.2.4. *5G services*

Table 95 Overview of 5G services to be implemented in the Remote Driving user story

5G service	Implementation
eMBB	Yes. To exchange raw sensors data between vehicles and infrastructure
URLLC	Yes. Low latency exchange between road entities

14.5.3. UCC#5, US#3: Tethering via vehicle using mmWave communication (KR)

14.5.3.1. *Motivation*

Due to the provision of highly developed networks corresponding to ever-increasing demands of getting connection to the Internet even in vehicles, people can enjoy variety of Internet services on the move. In-vehicle users may connect to the Internet with a help of appropriate mobility supporting networks such as existing 3G and 4G networks. Furthermore, the in-vehicle network access through a relay node that is deployed in the vehicle can provide some technical advantages that direct connections between UEs and base stations do not have (see below for the details). Since the relay node in the vehicle can provide tethering to passengers or nearby pedestrians owning Wi-Fi devices, they are able to experience bigger and safer data pipelines with the network's evolution towards 5G. Improved connectivity can be used for a better entertainment experience, such as high-definition 360 live streaming and virtual reality online gaming services. However, we cannot imagine this advanced experience without a high level of autonomous driving because drivers are easily distracted by immersive services. Therefore, high-level autonomous driving will promote the entertainment services in connected vehicles, and vice versa.

Technically, providing hundreds of Mbps data rate for every data hungry passengers in expressway buses is a specific goal. Considering, for example, 10 active users per bus and 10 buses per cell, those amount to total 10 Gbps of cell throughput. Therefore, this service will be a good practice of 5G eMBB (Enhanced Mobile Broadband) scenarios requesting very high data rates and low latencies. Since that service also needs mobility support over bus speed of around 100 km/h, methods for high spectral efficiency such as 256QAM or spatial multiplexing are largely limited. Therefore, to achieve the very high throughput, handling of very wide spectrum, i.e., mmWave, is inevitable.

The challenging aspects are as follows:

- Management of wide mmWave spectrum bandwidth reaching 1 GHz

- Robust mobility supporting algorithms with very low interruption time down to 2 ms
- Multiple beam management securing high reliability and availability for end users

14.5.3.2. Detailed description

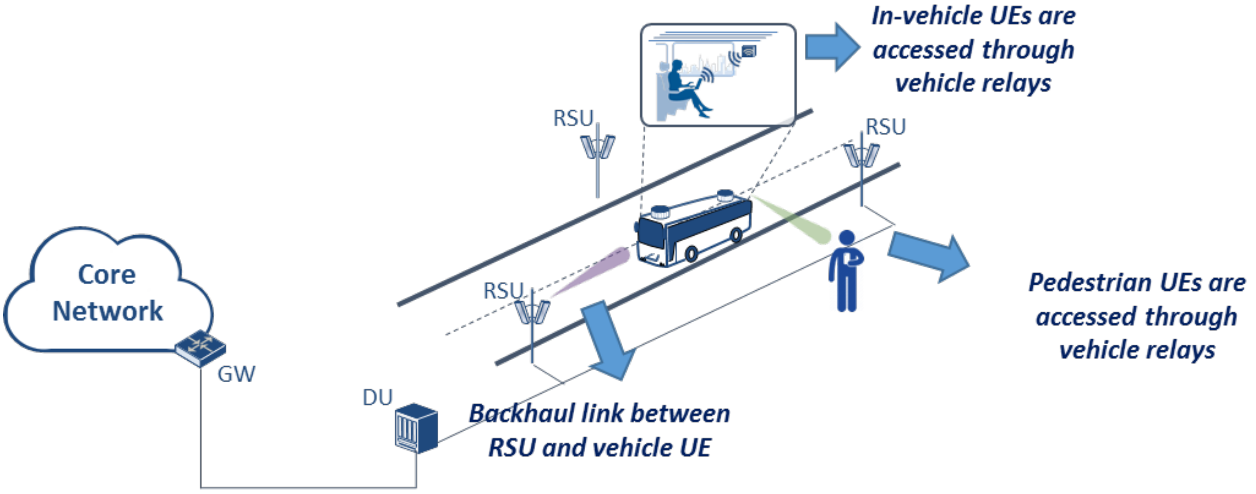

Figure 90 example of the Tethering via Vehicle user story from the KR local test bed.

Table 96 Overview of Tethering via vehicle user story

Use Case Category	Vehicle Quality of Service Support
User Story Leader	ETRI
Other partners	KATECH, SNetICT
Objective	Providing reliable and high-throughput Internet access to in-vehicle UEs and pedestrian UEs
Actors	Vehicle A, Occupant A, Network
Pre-conditions	• Vehicle A is V2X capable and is equipped with E-UTRAN access capability. • Occupant A has a mobile device that is V2X capable.

User Story flow	1. When Occupant A is riding in Vehicle A, their handset obtains access to the network via Vehicle A. 2. Vehicle A relays the communication between Occupant A and the Network using its own network access 3. When Occupant A parks Vehicle A to go for a quick shop nearby the communication between Occupant A and the Network continues via Vehicle A, as long as passenger A is in range of V2P communication.
Post conditions	Occupant A's handset saved battery power and potentially obtained higher throughput due to gaining network access via Vehicle A's network connectivity.

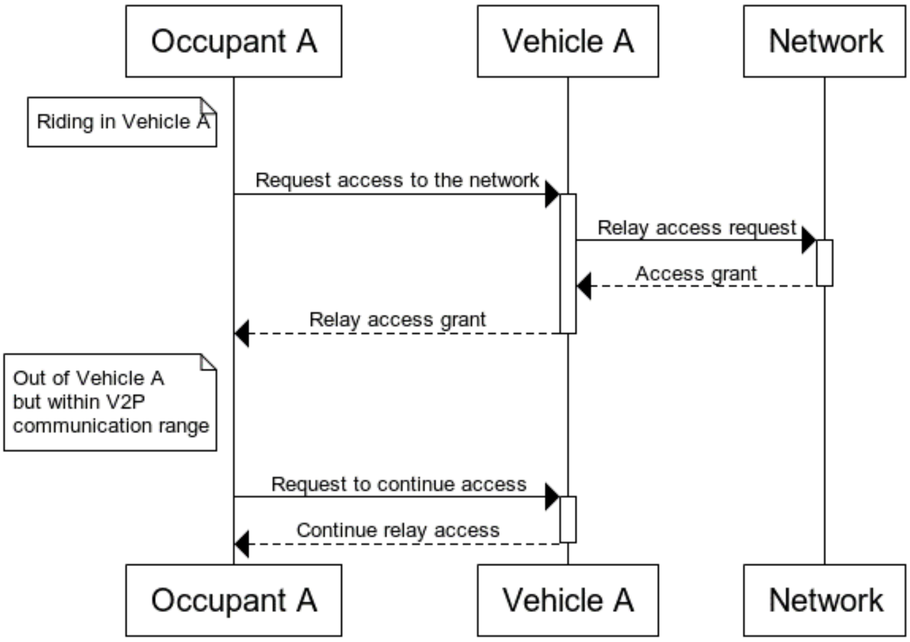

Figure 91 Tethering via vehicle sequence diagram

14.5.3.3. Beyond state of the art

Recently, with the proliferation of mobile devices and the emergence of a wide range of broadband applications (e.g., video on demand, virtual reality (VR), augmented reality (AR)), traffic demand for users on the move has been growing rapidly. However, the existing cellular systems including Long Term Evolution (LTE)/LTE-Advanced (LTE-A) are unable to offer wireless connectivity to vehicles that enables such services since these systems were primarily designed for low-mobility environments. For this reason, 5G-MOBIX will contribute to developing a mmWave-band 3GPP 5G NR V2I system with the following key enabling technologies to solve the technical challenges encountered in mmWave-band vehicular communications.

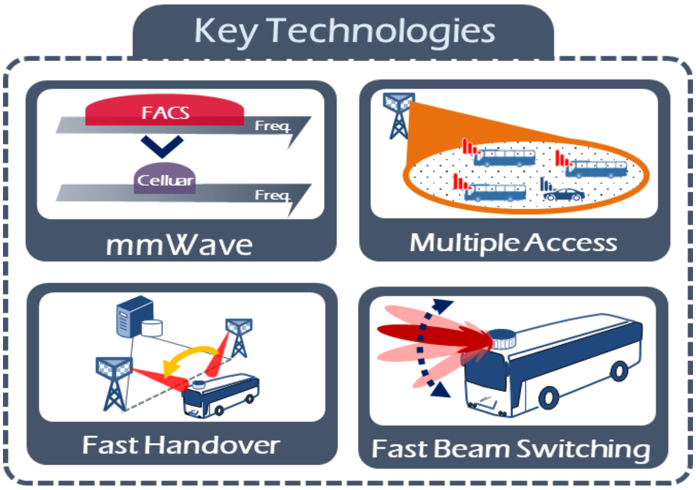

Figure 92 Key Technologies of Tethering via vehicle user story

- mmWave-based vehicular communications: by taking advantage of a vast amount of spectrum underutilized, mmWave enables high data rate transmission
- Multiple access: a technology that allows multiple vehicles in a cell covered by a BS to simultaneously receive MWB links for broadband Wi-Fi services. In addition, by effectively scheduling radio resources to vehicles in the coverage, multiple access technique is able to offer increased system throughput.
- Fast handover: a key technology to provide seamless handover to minimize the communication interruption time when a vehicle crosses cell edge.
- Fast beam switching: a technology to combat unexpected signal blockage and increase received signal quality.

14.5.3.4. 5G services

Table 97 Overview of 5G services to be implemented in the Tethering via Vehicle user story

5G service	Implementation
eMBB	Yes. To provide moving vehicles with a broadband mmWave-band V2I link that allows onboard passengers to experience high-quality connectivity to the Internet
URLLC	No
Other	No