5GMOBIX

5G for Connected, Cooperative and Automated MOBIlity on X-border corridors

D3.6

Report on trial readiness verifications

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Control sheet

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ABBREVIATIONS

Abbreviation	Definition
5G NR	5G New Radio
AD	Autonomous/Automated Driving
ADAS	Advanced Driver Assistance System
AI	Artificial Intelligence
app	Application
ASN.1	Abstract Syntax Notation One
CAM	Cooperative Awareness Message
CAN	Controller Area Network
CAV	Connected and Automated Vehicle
CBC	Cross-Border Corridor
CCAM	Cooperative, Connected and Automated Mobility
C-ITS	Cooperative Intelligent Transport System
CN	China
CoCA	Cooperative Collision Avoidance
CPM	Collective Perception Message
CTS	Centralized Test Server
CV	Connected Vehicle
C-V2X	Cellular Vehicle to Everything
DE	Germany
DENM	Decentralized Environmental Notification Message
DNS	Domain Name System
EC	European Commission
EDM	Edge Dynamic Map
eMBB	enhanced Mobile Broadband
eRSU	Enhanced Road-Side Unit
ES	Spain
ETSI	European Telecommunications Standards Institute

EU	European Union
FI	Finland
fps	Frames per second
FR	France
GDPR	General Data Protection Regulation
gNB	gNodeB
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GR	Greece
GUI	Graphic User Interface
HD	High Definition
HMD	Head-Mounted Device
HMI	Human Machine Interface
HO	Handover
IP	Internet Protocol
ITS	Intelligent Transport System
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
KR	Korea
LAN	Local Area Network
LBO	Local Breakout
LDNS	Local DNS
LiDAR	Light Detection and Ranging
LTE	Long-Term Evolution
MCC	Mobile Country Code
MCM	Manoeuvre Coordination Message
MCS	Manoeuvre Coordination Service
MEC	Multi-access/Mobile Edge Computing
MIP	Mobile IP
ML	Machine Learning

mmWave	Millimetre Wave
MNC	Mobile Network Code
MNO	Mobile Network Operator
MQTT	Message Queuing Telemetry Transport
MTU	Maximum Transfer Unit
NL	Netherlands
NSA	Non-Standalone Architecture
NTP	Network Time Protocol
OBU	On Board Unit
OEM	Original Equipment Manufacturer
PC	Personal Computer
pcap	packet capture
PCI	Physical Cell Identity
PGW	Packet Gateway
PLMN	Public Land Mobile Network
PPS	Pulse Per Second
PT	Portugal
PTP	Precision Time Protocol
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RCV	Remote Control Vehicle
ROC	Remote Operations Centre
RSI	Roadside Infrastructure
RSU	Roadside Unit
RTK	Real-Time Kinematic
RTMP	Real-Time Messaging Protocol
RTT	Round-Trip Time
RTTI	Real-Time Traffic Information
SA	Standalone Architecture

SAE	Society of Automotive Engineers
SIM	Subscriber Identity Module
SSH	Secure Shell
SSL	Secure Sockets Layer
TCP	Transmission Control Protocol
TLS	Transport Layer Security
TR	Turkey
TS	Trial Site
UCC	Use Case Category
UDP	User Datagram Protocol
UE	User Equipment
US	User Story
V2I	Vehicle to Infrastructure
V2X	Vehicle to Everything
vEPC	Virtual Evolved Packet Core
VM	Virtual Machine
VPN	Virtual Private Network
VRU	Vulnerable Road User
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WP	Work Package
X-border	Cross-border

EXECUTIVE SUMMARY

This deliverable reports on the verification performed in the different trial sites of 5G-MOBIX. The main objective of the verification is to ensure that all the components, systems, and solutions developed and integrated in WP3 are ready for running the trials and carrying out evaluation successfully. The verification process also addresses the readiness of the cross-border corridors (CBCs) and trial sites, i.e. the ability of the trials to start in a harmonised way and to produce consistent sets of data for evaluation.

The main verification tools for the user stories are the sequence diagrams and checklists. Starting from the sequence diagrams, the different checkpoints, where components developed by different partners interact which each other, are identified. The checklist contains tests for self-assessment to ensure that all the components developed in tasks T3.2-T3.5 are correctly integrated, and that the whole system works as expected.

The verification process is described for all user stories, and for the contribution of the local trial sites to the cross-border corridors, and the filled-in checklists and sequence diagrams are provided.

At the end of February 2022, the verification of all use cases is almost complete, and the use cases have proceeded to the actual trial phase. For a few user stories, not all functionalities (e.g. mmWave) are implemented, but a "basic" version of the user story is implemented, which is used for the first trials in WP4.

Due to technical reasons and due to delays caused by COVID-19 travel restrictions, especially for the contributions of the local trial sites to the cross-border corridors, some verifications are still ongoing. Only for 2 user stories, the completion percentage, which is calculated from the number of passed tests, partial fulfilled tests, failed and non-performed tests, is less than 80%. The final verification tests will be performed during March 2022, when the partners from the local sites can travel to the cross-border corridors.

1 INTRODUCTION

1.1 About 5G-MOBIX

5G-MOBIX aims to showcase the added value of 5G technology for advanced Cooperative, Connected, and Automated Mobility (CCAM) use case categories 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 plans to 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 also utilizes and upgrades 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 executes CCAM trials along two cross-border corridors (CBC) (Spain-Portugal and Greece-Turkey) and local trial sites (TS) (Finland, France, Germany, Netherlands, Korea, China) using 5G core technological innovations to qualify the 5G infrastructure and evaluate its benefits in the CCAM context.

1.1.1 5G-MOBIX user stories

5G-MOBIX first defined critical user stories needing advanced connectivity provided by 5G, and the required features to enable some advanced CCAM user stories in D2.1 [1]. The expected benefits of 5G for these identified user stories are planned to be tested during trials on the 5G corridors. Table 1 gives an overview of the user stories (US), grouped into five use case categories (UCC), which are tested and deployed in 5G-MOBIX. The local trials sites contribute to the CBCs by transferring locally deployed solutions to the CBC, as further described in Section 1.1.2.

Table 1: 5G-MOBIX user stories

UCC Id	UCC Name	Trial Site	No.	US Id	US Description
AdDr	Advanced Driving	ES-PT	1.1.a	LaneMerge	Complex manoeuvres in cross-border settings: lane merge for automated vehicles
		ES-PT	1.1.b	Overtaking	Complex manoeuvres in cross-border settings: automated overtaking
		FR	1.2	AssInfrastructure	Infrastructure-assisted advanced driving
		NL	1.3	CoCA	Cooperative Collision Avoidance
		CN	1.4	CloudAssisted	Cloud-assisted advanced driving
		ES-PT	1.5	CoopAutom	Automated shuttle driving across borders: cooperative automated system
Plat	Vehicles Platooning	GR-TR	2.1.a	SeeWhatISee	Platooning with "see what I see" functionality in cross-border settings
		GR-TR	2.1.b	5GPlat	Platooning through 5G connectivity
		DE	2.2	AsseRSU	eRSU-assisted platooning

UCC Id	UCC Name	Trial Site	No.	US Id	US Description
		CN	2.3	AssCloud	Cloud-assisted platooning
ExSe	Extended Sensors	ES-PT	3.1.a	HDMapsVehicle	Complex manoeuvres in cross-border settings: HD Maps
		ES-PT	3.1.b	HDMapsPublic-Transport	Public transport, HD Maps
		GR-TR	3.2.a	AssBCrossing	Extended sensors for assisted border-crossing
		GR-TR	3.2.b	TruckRouting	Truck routing in customs area
		DE	3.3	EDM	EDM-enabled ES with surround view generation
		FI	3.4	EdgeProcessing	Extended sensors with redundant Edge processing
		NL	3.5	CPM	Extended sensors with CPM messages
ReDr	Remote Driving	ES-PT	4.1	RCCrossing	Automated shuttle RD across borders: remote control
		FI	4.2	RedundantNE	Remote driving in a redundant network environment
		NL	4.3	5GPositioning	Remote driving using 5G positioning
		CN	4.4	DataOwnership	Remote driving with data ownership focus
		KR	4.5	mmWave	Remote driving using mmWave communication
QoS	Vehicle QoS Support	ES-PT	5.1	MediaPublic-Transport	Public transport: HD media services and video surveillance
		KR	5.2	Tethering	Tethering via vehicle using mmWave communication

The trials 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 aims to 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.

1.1.2 Contributions of the local trial sites to the cross-border corridors

This section presents the collaborations existing between local trial sites and the cross-border corridors. These collaborations are shaped as contributions in terms of hardware and software assets, aimed at complementing the CBC user stories or providing tools for benchmarking different implementations (e.g., different handover approaches). Table 2 gives an overview of the contributions of the local trial sites to the CBC, and the following subsections give more details on the contribution of the local trial sites.

Table 2: Cross-border corridor contributions from local trial sites

Local Trial Site	CBC	UCC	US	Cross-border corridor contribution
FI	GR-TR	Plat	2.1.a	LEVIS video streaming application
FI	ES-PT	ExSe QoS	3.1 (a or b)	Edge discovery service
FI	ES-PT	ReDr	agnostic	5G Multi-SIM OBU solution
FR	ES-PT	AdDr	1.1.a	5G Connected car
FR	ES-PT	ReDr	agnostic	5G Multi-SIM OBU solution
NL	ES-PT	AdDr	1.1.b	MCS application
DE	ES-PT	ExSe	3.3	Extended sensors solution, including 5G Connected Car, 5G Multi-SIM OBU, PC5 RSUs and MEC instances

For each local trial site, a general description of the contributions is presented with sections describing their aim toward the project goals, deployment planning, and current status.

1.1.2.1 Finnish Trial Site contributions

The FI TS will contribute to the GR-TR CBC with a LEVIS video streaming client and server, that will be trialled under the See-What-I-See User-story. It will also contribute to the ES-PT CBC with 1) an Edge Discovery Service that will provide DNS-like name resolution and 2) a multi-SIM OBU solution providing handover based on mobile IP tunnelling technology. The contributions are detailed next.

LEVIS video streaming

This contribution will transfer the binaries of LEVIS video streaming, which is used in the Remote Driving US of FI TS, to the See-What-I-See application devices in the GR CBC. More particularly, the binaries of the primary application will be remotely installed in both the server and the client devices which will be used at the GR-TR CBC tests and trials. Being the major part of the application's functionality, the binaries are integrated with the See-What-I-See management module which manages the platooning members' registration during its dynamic formation and deformation. The application devices will be installed at the GR edge server (application server) and in Ford trucks (client devices) for the US scenarios execution.

Edge discovery service

This contribution of an edge discovery service solution to the CBC ES-PT is to help the 5G UE find the IP address of a MEC in the visited network (see Figure 1). The system is built on top of Domain Name Server (DNS) to ensure compatibility with existing applications, i.e., the edge platforms in Spain and Portugal. The MECs register themselves in a cloud-located coordinator, which instructs the DNS server on how to reply to different domain names.

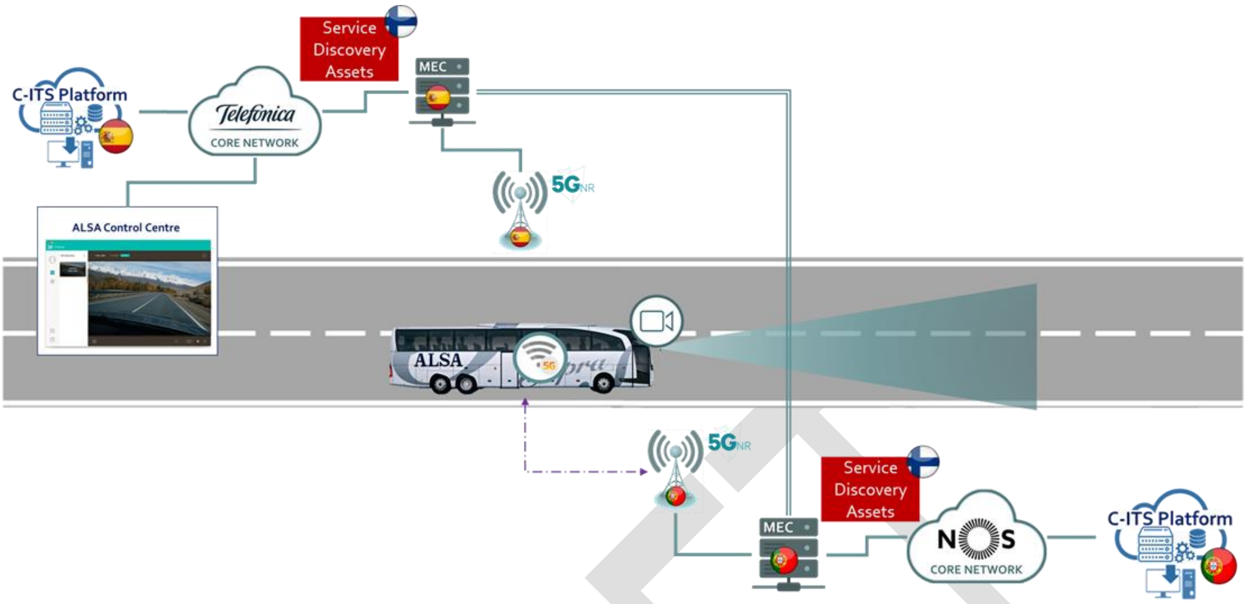

Figure 1: FI-TS edge service discovery contribution to the ES-PT CBC

In the service discovery architecture, a Local DNS (LDNS) deployed in the core is a resolver for relaying and caching the DNS queries in the local network. The role of the LDNS is to accelerate the DNS query process and the response is purely decided by the cloud-located DNS server. The service discovery mechanism also supports service migration. The UE needs to use a DNS query to find the IP of the MEC whenever its connected-gNB or its IP address changes. If the newly found MEC is different from the previous one, the UE can migrate from the old MEC to the new one. During the stage of migration, the UE has access to both the old and the new MECs so that it can implement application-specific logic for data transfer, e.g., move its user data from the old MEC to the new MEC.

Multi-SIM OBU solution

The OBU considered here is a multi-SIM solution based on a router from Goodmill Systems[1] used for critical communications scenarios. This multi-SIM OBU has been in use in local trials in FI-TS for both the remote driving and extended sensors user stories. As a contribution to the ES-PT CBC it will be used for agnostic testing in the ES-PT CBC to provide insights on the performance of multi-SIM implementations in realistic cross-border environments and comparisons against conventional roaming implementations. The agnostic testing campaign will be conducted in collaboration with the FR-TS that has an alternative multi-SIM implementation.

The multi-PLMN operation of the FI-TS OBU is enabled by the use of Mobile-IP (MIP) tunnelling approach. The MIP implementation provides service continuity, security, and reliability through encrypted tunnels, fast tunnel switch-over, session persistence, selecting always the best (or prioritised) link, or alternatively aggregating traffic over multiple links. Moreover, the approach provides flexibility for ensuring service

[1] https://goodmillsystems.com/

continuity of both 3GPP access (5G NSA/SA, public LTE, private LTE, etc.) and non-3GPP access (Wi-Fi, satellite, etc.). Figure 2provides a high-level illustration of multi-PLMN operation with the FI-TS multi-SIM OBU in an environment with overlapping coverage from two 5G PLMNs. The MIP GW server terminates MIP and VPN tunnels coming from OBU, with MIP providing session persistency while VPN encrypts traffic. The Goodmill Manager provides an admin interface for configuring and monitoring the OBU.

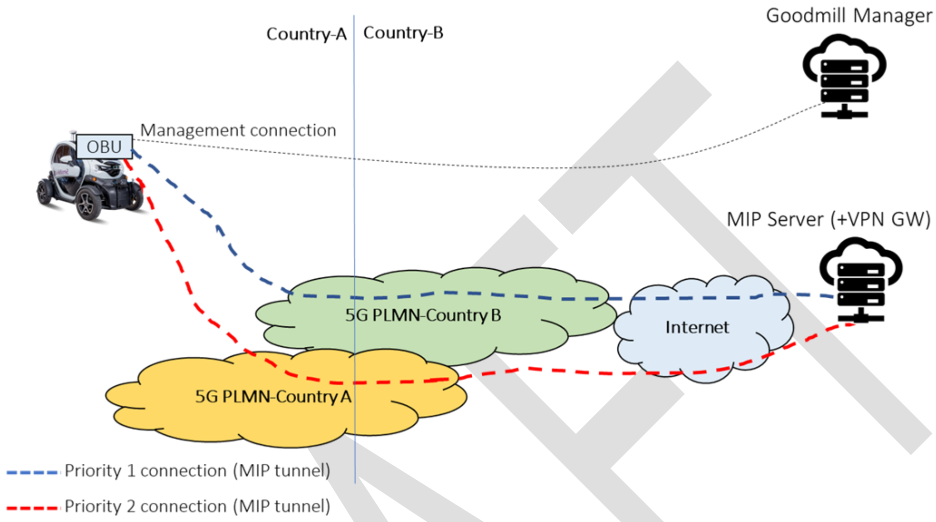

Figure 2: Multi-PLMN connectivity using the FI-TS multi-SIM OBU solution

Deployment planning

Regarding the LEVIS video streaming, the binaries were progressively installed and tested in their respective devices of the See-What-I-See application between March 2021 and July 2021. The final verification successfully took place in December 2021 (M38) when the devices were placed, integrated, and tested in Ford trucks (through their connection with IMEC OBUs).

For the edge discovery service solution, the deployment to the ES-PT CBC has been completed since September 2021 (M35). To that end, the deployed technology components included a server script for automatic registration, an authoritative DNS server, and client scripts for PLMN-change detection, service discovery, and migration.

For the multi-SIM OBU, the deployment of the OBU will be done on-site at the ES-PT CBC in the vehicle provided by the FR-TS. However, deployments of the anchor MIP server and some of the components of the KPI measurement will be done remotely in advance prior to travel to the CBC. In this case, the NOS data centre has been identified as the host for the virtual server and software components for the measurement tool.

Deployment status

The complete deployment of LEVIS video streaming binaries has been done. The remote supervision of the application's smooth functionality will take place during the GR-TR CBC trials with any potential intervention if needed. As noted previously the deployment of edge discovery service solution to the ES-PT CBC is also complete and available for trials to be conducted within M40-M42. For the multi-SIM OBU to ES-PT CBC, the remote installation and testing of server-side components are ongoing, whereas the deployment of the actual OBU hardware will be done at the actual trials tentatively in M41.

1.1.2.2 *French Trial Site contributions*

The French trial site will contribute to the ES-PT Cross-border corridor with 1) a solution for seamless handover using a multi-SIM approach and 2) transferring a 5G-connected vehicle for benchmarking and inter-operability tests. The two contributions are detailed next:

Seamless handover using a multi-SIM solution

This contribution provides the implementation of a solution to reduce the negative effects of multi-PLMN handovers at the corridor: 5G to 5G, 5G to 4G, or 4G to 5G using a dual-SIM solution.
FR TS will use an intelligent router solution, connected to its OBU, which allows the UE to keep multi-SIM connections with PLMNs ensuring continuity with the application endpoint (in the cloud or the MEC). Based on continuous monitoring of available networks (4G, 5G) and their quality, the intelligent router selects and connects to two PLMNs. Specifically, the first 5G interface will stay connected to the available PLMN while the second one will be in monitoring mode, scanning for secondary connection, and when it sees a secondary stable connection, it will connect the second interface to the secondary PLMN. At the reception, a software module, so-called aggregator, aggregates data transmitted over the different PLMNs and provides the aggregated data to the target application. An overview of this solution can be checked in Figure 3.

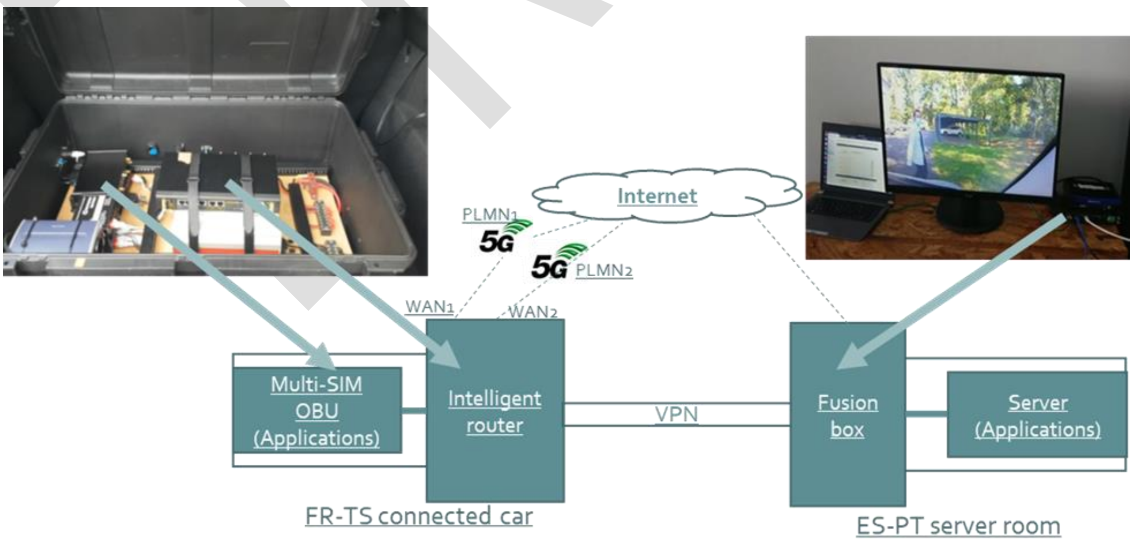

Figure 3: Multi-SIM solution for seamless handover using Pepwave device

Agnostic tests will be carried out to evaluate the performances of the contributions. In this scheme, the connected vehicle will be equipped with a 5G OBU and intelligent router. The vehicle will communicate with a server in the cloud, called the Speed fusion box, where an aggregator module performs flow aggregation, packet reordering, and error correction functionalities.

At the CBC, the FR TS dual-stack OBU, the intelligent router will be integrated into the FR TS connected vehicle, and the proposed seamless handover solution will be tested under the CBC multi-PLMN scenario and compared against the ES-PT single-SIM solution and the FI multi-sim solution. It should be noted that the FI TS solution will be integrated into the FR TS connected vehicle, and both sites will use the same performance measurement tool (DEKRA tool) in order to carry out the FR TS and FI TS test in the same/similar scenarios and identify the strengths/weaknesses of individual solutions.

5G connected vehicle for benchmarking and inter-operability tests

The second contribution of the FR TS is bringing a connected vehicle to the ES-PT corridor to interoperate with the other "local" vehicles and the infrastructure, particularly the ES-PT ITS server. The vehicle will be equipped with a 5G OBU integrated with a complete protocol stack and application layer modules, including an agent of Predictive QoS developed by the FR TS targeting the user stories developed in the ES-PT corridor: US1 of Advanced Driving category (Complex maneuvers in cross-border settings) we test inter-operability between the FR TS vehicle and ES-PT vehicles/network. Different communication flows will be tested during these benchmarks including Cooperative Awareness Messages (CAMs) and Collective Perception Messages (CPMs).

Figure 4: 5G Connected vehicle from the French trial site, which is demonstrated in the ES-PT CBC

Deployment planning

Both contributions have been developed and tested in France ready to be shipped to ES-PT by September 2021.

Concerning the multi-SIM contribution FR-TS has received two SIM cards in 2020, one for the Spanish network and the other for the Portuguese network. The 5G multi-SIM OBU and the Pepwave router have been installed in a connected vehicle and their functionalities have been tested and validated with a server in France and a server in the UK (at Catapult's premises). The installation of the server, Fusion Box, at ES-PT CBC requires an Ethernet connection, one public IP, and two specific port numbers (32015 and 4500). The requirements have been submitted to ES-PT CBC in September 2021. NOS, an ES-PT partner and the Portuguese telecom operator, analysed if the server can be installed at the NOS infrastructure. As soon as the condition is accepted, the equipment will be shipped to ES-PT, and a FR TS team will make the installation of the system.

Concerning the connected vehicle contribution, the connected vehicle is ready to be shipped to ES-PT, equipped with a 5G OBU, the protocol stack, and application layer modules. Interoperability tests between the FR TS protocol stack with ES-PT protocol stacks have been carried out in 2020 and 2021. The vehicle has been heavily used for FR TS advanced driving use case testing, and it will be used for the ES-PT variant of the advanced driving use case tests. The use case tests at ES-PT require closing the new bridge, and all the vehicles that run on the closed road need authorisation from the Spanish road operator. An authorisation from the road operator has been received in February 2022. The contribution has been planned during the Week 12 of 2022.

Deployment status

Necessary remote interoperability tests have been carried out. Trials are planned for the week 12 of 2022.

1.1.2.3 Dutch Trial Site contributions

The NL TS will contribute to the ES-PT CBC with an application supporting the Manoeuvre Coordination Service (MCS) used in Cooperative Collision Avoidance (CoCA) user story.

The MCS application, which is deployed in the Dutch trial site and which enables infrastructure centred management with MCMs, is deployed at the ES-PT cross-border corridor. The OBUs, which are used in the NL trial site, are transferred to the ES-PT CBC. The MCM/MCS communication framework will be benchmarked with the Overtaking user story in the ES-PT CBC. Two OBUs will be installed in the vehicles participating in the scenarios. With this contribution, NL and ES-PT intend to benchmark the outcomes of an autonomous lane merge between the in-vehicle decision-making approach implemented in ES-PT and the infrastructure decision-making approach implemented in NL.

Deployment planning

The MCS application was installed in a VM offered by Telefonica, and connected to the Spanish 5G test network. Due to issues with the planned timing of the trials in NL and in the ES-PT CBC, two OBUs were developed by VTT and sent to the ES-PT CBC for testing. The OBUs are identical to the ones used in the Dutch trial, consisting of laptop, 5G-modem, and GNSS receiver. In the overtaking scenario are 3 vehicles involved: the automated vehicle which will overtake a slow vehicle, and a faster vehicle in the left lane overtaking both other vehicles. The OBUs, transmitting and receiving MCMs, are installed in the automated vehicle and in the slow vehicle. The CAM messages sent by the fast vehicle are also used by the MCS application.

Deployment status

Verification tests were performed in Autumn 2021 remotely in Tampere, and on-site in October. The NL site participated to Overtaking trials performed by the ES-PT CBC in November 2021, but at that moment handover and roaming between the Spanish and Portuguese networks did not work. New trials are planned for mid-March 2022.

1.1.2.4 German Trial Site contributions

The complete Extended Sensors demonstrator is being transferred to the CBC and will be trialled there. This includes:

- Two 5G dual modem solutions.
- MEC instances (WebRTC proxy and EDM) deployed in Telefonica's MEC and NOS MEC.
- A 5G connected vehicle, equipped with environmental sensors.
- One RSU with 5G PC5 connectivity.

The dual modem (dual SIM) approach of DE TS will be compared with the roaming (single SIM) available in the ES-PT CBC with respect to the Extended Sensor use case.

The PC5 RSU can also be used in the ES-PT CBC use cases as beaconing for either service announcement or to alert that the vehicle is approaching the border and that a network handover/roaming might occur soon.

1.1.3 Deployment planning

The planning is divided into several stages: 1) local testing of all the contributions in the DE TS, 2) remote testing of services deployed in the CBC MECs, 3) road testing in the CBC and collection of evaluation data.

A road trial campaign is planned for the first week of March 2022. Additional trial campaigns are foreseen depending on the obtained results.

1.1.4 Deployment status

All the components have already been successfully tested in Berlin. The DE TS MEC services have already been deployed in Telefonica's and NOS MECs in the ES-PT CBC. Some remote tests have also been performed to test inbound and outbound data transfer as well as MEC interconnection. However, the road trials have been delayed due to the problems in the ES-PT CBC networks. A road trial campaign is planned for the first week of March 2022.

1.2 Purpose and structure of the deliverable

This document is the deliverable D3.6 "Report on trial readiness verification", which is the output of task T3.6 "Verification" of the 5G-MOBIX project. The main objective of this task is to verify that all the components, systems, and solutions developed and integrated in WP3 are ready for running the trials and carrying out successful evaluations. The verification addresses also that all systems are ready to initiate the trials in a harmonised way to produce consistent sets of data at any corridor and trial site. The task corresponds to Phase 3 of the 5G-MOBIX roll-out plan (Figure 5), as described in deliverable D3.1 [2]. The first version of this document addressed the verifications up till April 2021. After verification, the use cases proceeded to the first trials. However, for multiple user stories, not all planned functionalities, such as handover or logging support, were working in April 2021, and both development and verification on these aspects continued, also after the start of the first trials. This document provides an overview of the verification up till end of February 2022.

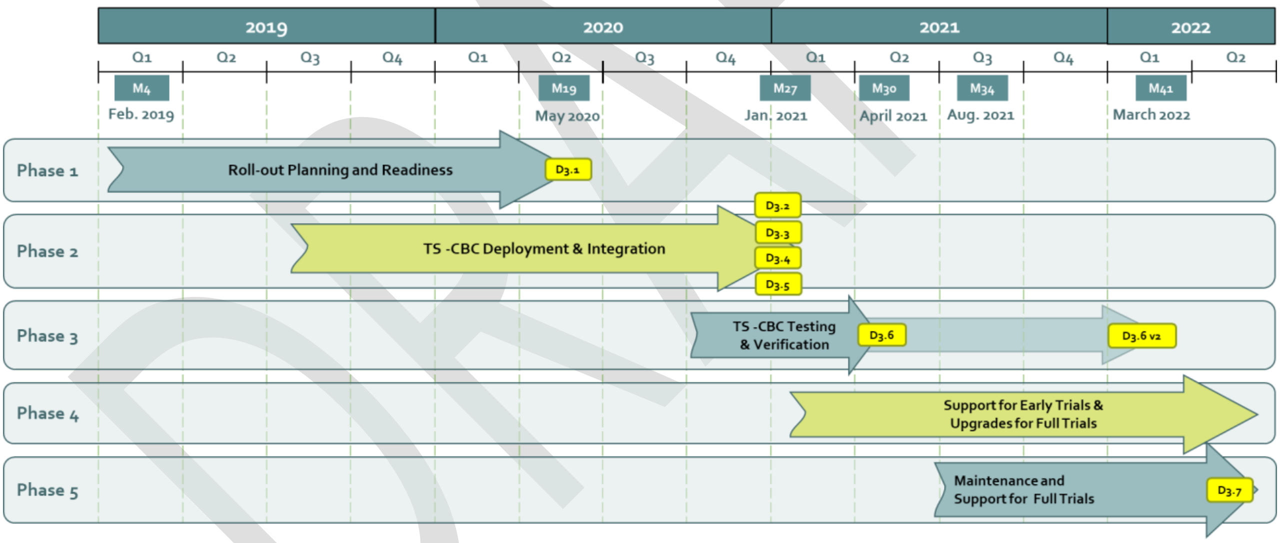

Figure 5: 5G-MOBIX WP3 Roadmap

The first part of the deliverable describes the verification methodology and the second part of the deliverable reports on the verification of the different system components of the user stories.

1.3 Intended audience

The deliverable D3.6 is a public deliverable and is addressed to any interested reader.

1.4 COVID-19 impact

The COVID-19 pandemic caused a substantial delay in the deployment and integration activities in Phase 2 of 5G-MOBIX WP3 (Figure 5). In addition, the travel restriction requirements prevented the travel of research personnel to the actual test sites and prevented vehicles to cross borders. In order to mitigate the impact of the travel restrictions on the verification activities, verifications were performed remotely, either by performing tests on other locations than originally planned or by sending equipment to local partners and providing remote support during testing.

The COVID-19 pandemic especially affected the contribution of the local test sites to the cross-border corridors. In several cases, the equipment needed for the cross-border corridors is also needed for the Test Site verifications and evaluations and could only be transferred when the local tests have been performed.

2 VERIFICATION METHODOLOGY

2.1 Overall target

The verification process in T3.6 aims to provide the necessary methodology and tools to ensure that the trial sites are ready to initiate the trials and to evaluate the components and systems of trial sites successfully.

The verification addresses the necessary 5G infrastructure and technology, vehicle adaptations, and software tools in order to enable the corridor trials as specified in WP2, integrated in WP3, executed in WP4, and evaluated in WP5. To commence with verification, the above-mentioned subjects must be mature, stable, and in principle ready for running the trials.

2.2 Dependencies of verification

The generic verification development process is highly dependent on other 5G-MOBIX WPs and their inputs, as described in Figure 6. The development process contains the following elements:

1. T3.6 provides an overall description of the verification process for reference in T3.1, which provides the overall description of verification for the individual deployment tasks T3.2-3.5. This has been reported in D3.1 [2]
2. The development of verification methodology, test cases, and tools in T3.6 are processed this way:
   - 2.1. A checklist has been developed to verify the correct integration and working of the different components, which were developed in tasks T3.2-T3.5, and are reported in D3.2-D3.5 [3] [4] [5] [6]. The checklist is further described in Section 2.3.3.
   - 2.2. WP2 provides the user story sequence diagrams of each corridor and trial site for reference. These sequence diagrams are annotated to identify checkpoints for testing.
3. The verification methodology, test cases, and tools are provided for guidance by T3.6 for verification work at the local level (Phase 3).
4. The local verification is performed across the cross-border corridors and trial sites, based on the guidelines, and report back their verification results to T3.6.
5. The verification methodology is also applied to the transferred use cases at the cross-border corridors.
6. The results of both the local verification (step 4) and the verification of the transferred use cases are integrated in the report D3.6. Successful verification results indicate that the user stories are in principle ready to start execution in WP4 'Trials' and to support WP5 'Evaluation'.

   The development, verification, and trial is often an iterative approach. Trials in WP4 may start with a basic version of the user story, which does not yet implement all planned functionalities. Verification continues then after the start of the trials, addressing the more advanced features of the user story.

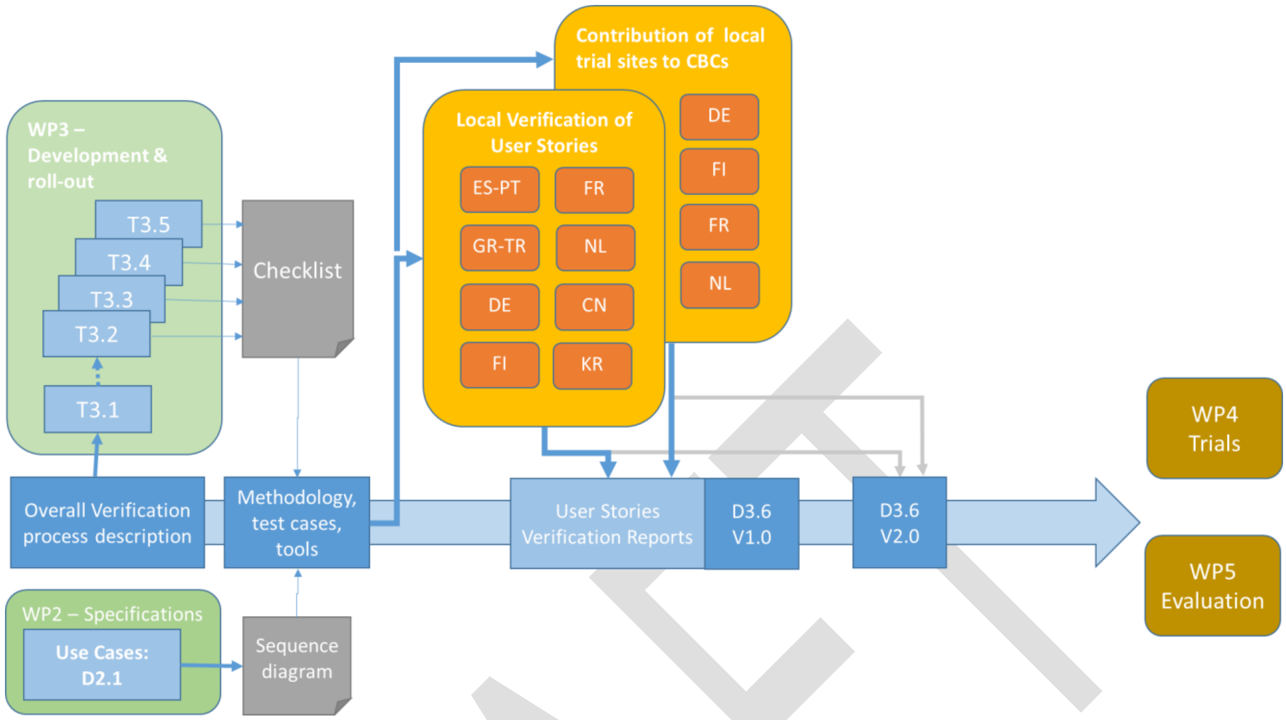

Figure 6: D3.6 Development Process in Wider Context

Specifically, in WP5, T5.2 should comprehensively evaluate the technical performance of technologies and solutions implemented in the corridors and the trial sites and, especially, the cross-border behaviour of the network and solutions implemented, taking into account the architecture and technical specifications of the user stories defined in WP2 and the common evaluation methodology described in D5.1 [7].

2.3 Verification process

2.3.1 User story verification

The verification task concentrates on the user stories for each corridor and trial site, which are summarized in Table 1, and on the contribution of the local test sites to the cross-border corridors (Table 2).

During the verification process, the technologies of the four major domains, namely 5G network technologies, CCAM facilities, in-vehicle systems of the CAVs as well as cyber-security and privacy functions are addressed. Verification includes both the standalone verification of the different components that have been developed by the partners and verification of the integration of the components. For the verification, the following inputs are used:

- A list of all the components used in the user story, which are provided by the partners, such as the vehicles and the applications on the vehicle or the OBU, roadside equipment, other equipment such as smartphones, servers, and applications running on the servers, mobile networks, and MECs.

- A sequence diagram of the user story. The WP2 specification deliverables (D2.1 [1] and D2.3 [8]) defined the contents of the sequence diagrams for each user story. For several of the user stories, there are different scenarios, related to different manoeuvres or different communication configurations.

2.3.2 Sequence diagrams

The sequence diagrams serve as the main tool for the verification. The sequence diagrams define the data flow for each of the user story scenarios. The verification process concentrates on the data communications between components that are provided by different partners. Cross-border corridors and trial sites carry out the actual verification tests using the user story scenario specific test cases. The test cases are targeted to the *checkpoints*, where information exchange takes place between components developed by different partners.

Figure 7 gives the example of the sequence diagram for the user story CoCA (Cooperative Collision Avoidance), for the scenario where a CoCA application at the MEC gives advice to the vehicles. In this example, two vehicles (a Connected and Automated Vehicle and a Connected Vehicle) are on collision course and transmit Manoeuvre Coordination Messages (MCM) to a MEC application, which assesses the risk of collision and provides advice, such as lane change, to the vehicles.

The different checkpoints in the sequence diagram are identified. The checkpoints correspond to either interactions between different components or to outputs of specific components, e.g. algorithms for collision detection. The checkpoints are coloured, corresponding to whether there is only a single actor involved in the development (orange) or several actors (green). The verification will concentrate on the checkpoints involving different actors. The blue cells indicate the responsible partners for the different components.

For each of the multi-actor checkpoints, the required tests will be identified. The test definition includes the test case objective, the components and the partners to be involved, and where the test will be performed. In order to use the resources well, e.g. in order to avoid travel and transport of vehicles over long distances, it should be assessed whether and how tests can be performed remotely.

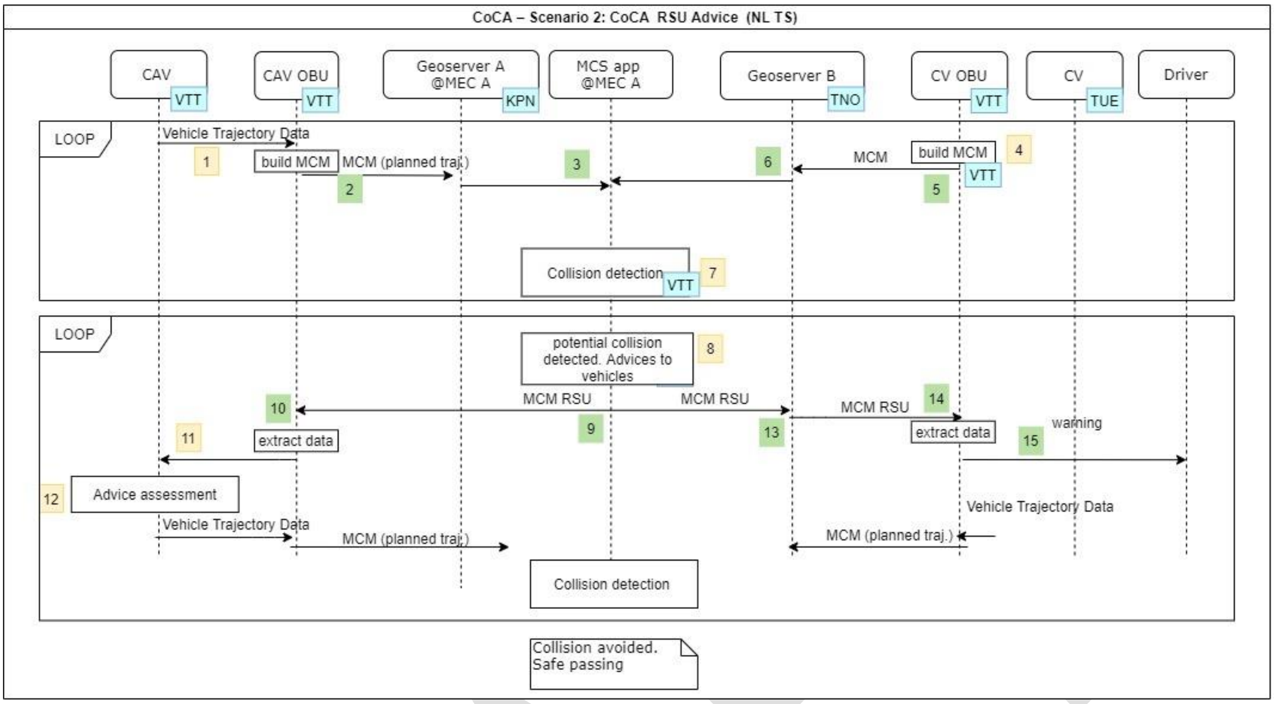

Figure 7: Sequence Diagram for RSU Negotiation Scenario of CoCA User Story

Table 3: Checkpoint test definitions for the CoCA scenario with MEC application

Check-point	Multi-actor?	Test objective	Component(s)	From	To	Verification location
1	n	import of vehicle data (i.e. data elements of MCM) to OBU	CAV control, CAV OBU app	VTT	VTT	VTT
2	y	transmission of MCM to MEC	CAV OBU app, MEC	VTT	KPN	Remote
3	y	reception of MCM and transmission to MEC CoCa app	MEC, MEC CoCA app	KPN	VTT	Remote
4	n	building of MCM	OBU app	VTT	VTT	VTT
5	y	transmission of MCM to MEC	CV OBU app, CV OBU comm., MEC	VTT	TNO	Remote

Depending on the test conditions, remote verification can be realized through a remote connection to servers, exchange of files containing the messages to be transmitted, or by sending, e.g., modem equipment to the location where the test is realized.

Test cases have to be defined for the checkpoints, not only for the transmission of the message, but also for setting up and activating the connection between the different components involved in checkpoints.

Test cases can address more than a single checkpoint, e.g. for checkpoints 2, 3, and 10 in Figure 7, a test case can be defined to assure that a message transmitted by the vehicle OBU is received by the application in the MEC and that the output message of the MEC application is received back by the vehicle OBU so that the interaction between the vehicle (from VTT, Finland), the MEC (from KPN), and the MEC application (from VTT) could be tested in a single test session.

2.3.3 Checklist

The verification of the components is made through self-assessment by the developing partners. A checklist has been developed for supporting the self-assessment. The tests for the checklist are listed in Table 4. The different issues are grouped in different categories, viz.

- Functional issues
  - UE related issues: vehicle, OBU, infrastructure, and ITS server related issues
  - Network related issues: 5G network and handover related issues
- Non-functional issues
  - Privacy and security related issues
  - Logging related issues

Development of the use cases is an iterative process, and not all the functionalities which were planned, were available in mid-2021 when the trials were planned to start. For those user stories, for which not all functionalities were developed, “basic” versions were defined, which were then used for the first trials. This deliverable will report the results for the versions of the user stories, which were ready by the end of February 2022. For most of the user stories the full version of the user story is evaluated, for a few the basic version which does not have all functionalities. For these user stories, the checklists are completed for both the “basic” and the full version of the user story. Tests, which are relevant for both the basic and the full version, are performed for the full version and inherited by the basic version. For those functionalities of the full version, which are not yet implemented, a specific test is performed for the basic version.

Table 4: Issues addressed in the verification checklist

Functional issues	
UE related issues	
Vehicle related issues	
V1	All CAVs are ready and available for the trials
V2	The physical components are integrated and operate correctly

V3	The physical components, integrated in the vehicle, send the correct information
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated
V5	The vehicle applications are correctly installed
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components
V7	Messages and data content and encoding have been agreed between partners
V8	The vehicle has safety measures in place to allow the driver to take control
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received
OBU related issues	
V10	All OBUs are ready and available for the trials
V11	The OBUs are correctly installed in the CAV/CV
V12	The applications in the OBU behave as expected and are validated
V13	The OBUs can manage and run 3rd party CCAM applications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity
V15	The OBUs connect and have access to the 5G network
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)
V18	The OBUs allow for improved positioning (compared to GNSS positioning)
V19	Synchronisation measures are used for the OBU
Infrastructure related issues	
I1	The availability of the infrastructure sensors is assured
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity
I3	The infrastructure sensors connect and have access to the 5G network
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding
I5	Synchronisation measures are used for the infrastructure
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data

External servers / ITS Centers	
S1	External servers and software, which are needed for the user story, are available
S2	External servers are connected to the network and accessible by all partners needing access
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated
S4	Messages with the servers can be exchanged according to the relevant specifications
S5	Synchronisation measures are used for the server
Other end-user devices (e.g. VRUs, smartphones)	
E1	Other end-user devices, which are needed for the user story, are available
E2	End-user devices are connected to the network
E3	The end-user devices have a live connection to MEC over 4G/5G connectivity
E4	The application algorithms on the end-user device are installed correctly and work as expected
E5	The end-user devices are capable to transmit the relevant (C-ITS) messages according to the relevant standard and encoding
E6	Synchronisation measures are used for the server
Network related issues	
5G network related issues (incl. MEC issues)	
N1	The MEC can manage and run 3rd party CCAM applications
N2	All partners have access to the needed interfaces and infrastructure
N3	MEC applications can handle the relevant C-ITS messages
N4	The complete test area is covered by the 5G-networks
N5	MEC access is provided for the whole test area
N6	All MEC applications and data logging are synchronised
N7	Data is exchanged between MECs through agreed protocols
N8	The algorithms for geolocation and filtering of messages work as expected
Network handover related issues	
N9	MNO1 can manage the connectivity handover procedures with MNO2
N10	MEC1 can connect with MEC2 and vice-versa
N11	The UEs can roam between MNO1 and MNO2
Non-Functional issues	
Privacy and security issues	
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…

P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)
Logging related issues	
L1	Logging is in place for all components
L2	Procedures for starting logging are in place
L3	Logging formats comply withthe agreed format
L4	Logged data can be uploaded to the CTS
L5	All data required is logged
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)

The checklist is filled in as an Excel document. For each test the following information has to be provided: responsible partner, test result (Passed / Fail / Partially Passed / Not relevant / Not tested), and comments, describing how the test has been performed and the test results. The test result is based on a self-assessment by the responsible partner, whether the criteria mentioned in the scope of the test have been fulfilled.

It should be noted that there are no explicit KPIs related to the verification tests, since these merely serve for the functional and non-functional correctness of the development and integration. For the KPIs and associated tests, the reader is referred to deliverables D2.5, D5.1 and D5.2 in 5G-MOBIX.

When reporting the checklists in this report, a completion percentage is calculated for each group of issues. The completion percentage is calculated as:

(#passed + #partly/2)/ (#passed +#partly + #failed + #not_tested).

The Excel document includes a supporting worksheet for the description of the components, used as a reference for describing the tests, as well as the sequence diagram, with annotation of the checkpoints. These checkpoints are used as references in the test description.

2.4 Partner involvement for verification

The local experts of the cross-border corridor and trial sites should run the verification procedures at the site level. Thus, the procedure to run the tests should be made as simple and as descriptive as possible. Each site is responsible to agree on which entity would be the most convenient actor for the task. The cross-border corridor or trial site manager/leader is in charge of the site's verification results and their reporting. The partner involvement and resources for verification are agreed locally and managed by the local partners.

3 VERIFICATION RESULTS

This chapter describes the results of the verification for the different trial sites. The contribution of the local trial sites to the cross-border corridor is reported under the local trial sites.

3.1 Spain-Portugal Cross-Border Corridor

Due to safety reasons, the first trials in ES-PT CBC have been performed at low speed in a closed environment in order to fine-tune the working of the CCAM functions with the 5G capabilities. In particular, at the first stage, the activities of verification have been carried out in CTAG test tracks (Figure 8) on the ES side with the vehicles and OBUs provided by CTAG and under the Pilot 5G network provided by Telefónica and managed by Nokia ES in the framework of 5G-MOBIX project.

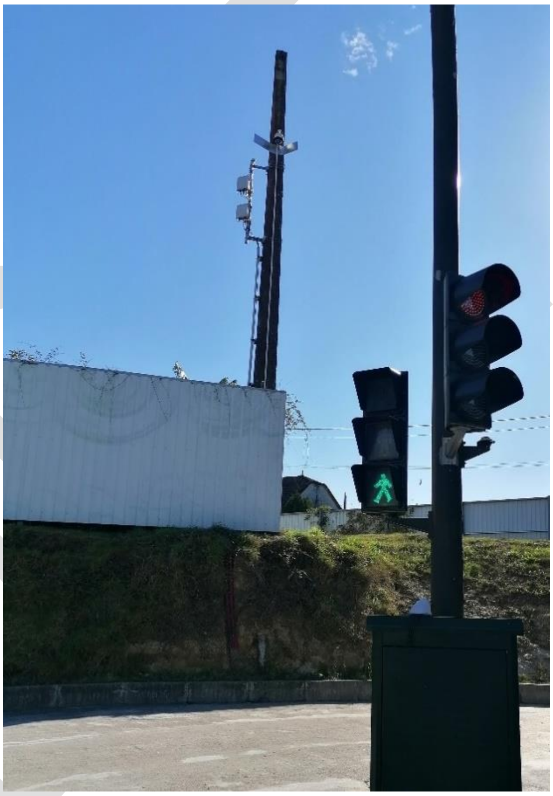

Figure 8: 5G antenna in CTAG's track used for the verification

After these first tests, the USs have been moved to the real environment (Figure 9) where the full trials are being deployed, performing verification tests in both the ES side and the border between ES and PT for most of the USs to check both the driving behaviour and the network capabilities.
As a result, the functionality tests are being more than satisfactory, and the efforts are in Q1 2022 being focused on finishing the network configurations to test the roaming and also the impact of the handover process.

The analysis of the logs is providing results for the network KPIs in range with the target values, meaning in addition that all the required measurements are being captured and the devices are showing the expected synchronization. Specific results are shown in the subchapters below and also the current progress in the common data format.

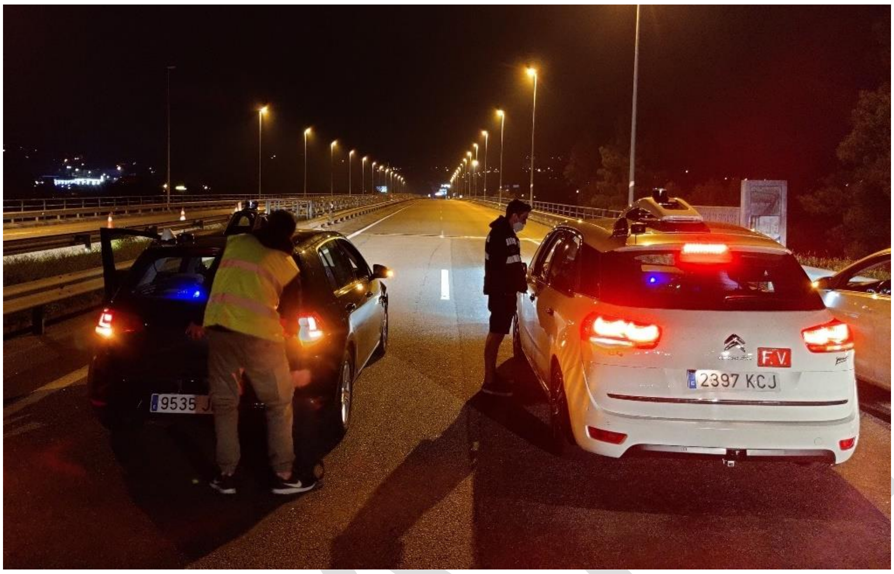

Figure 9: Verification tests at the ES-PT border (New Bridge)

Some non-US related tests have been performed in order to qualify in advance: the devices, the 5G integration, and the connectivity in the verification environment used for all the tests. These tests are common to most of the USs.

The first test consisted in checking the connectivity between the CTAG's OBU and the antenna provided by Telefónica in CTAG's test tracks (Figure 8). The results obtained (Figure 10) show that the OBU is properly connected to the ES network, in both LTE and NR 5G-NSA bands, with the expected values of MCC = 214, MNC = 38, and PCI =440.

```
root@imx6qdlhmcu:~# busybox microcom -s 115200 /dev/ttyUSB2
at+qeng="servingcell"
+QENG: "servingcell","NOCONN"
+QENG: "LTE","FDD",214,38,580940A,440,1301,3,5,5,8EF9,-109,-9,-81,17,15,150,-
+QENG:"NR5G-NSA",214,38,440,-72,32,-11,651648,77
```

Figure 10: Radio parameters collected in CTAG's test track

The services used in Advanced Driving and Remote Driving UCCs are installed in VMs hosted by the MEC. In this case, the values of the latency and packet loss are provided in a simultaneous ping from the OBU to the ES MEC (Figure 11) and to the VM hosting the MQTT service (Figure 12).

```
root@imx6qdlhmcu:~# ping 172.19.166.68
PING 172.19.166.68 (172.19.166.68): 56 data bytes
64 bytes from 172.19.166.68: seq=0 ttl=63 time=21.224 ms
64 bytes from 172.19.166.68: seq=1 ttl=63 time=25.590 ms
64 bytes from 172.19.166.68: seq=2 ttl=63 time=24.880 ms
64 bytes from 172.19.166.68: seq=3 ttl=63 time=19.740 ms
64 bytes from 172.19.166.68: seq=4 ttl=63 time=10.464 ms
64 bytes from 172.19.166.68: seq=5 ttl=63 time=20.179 ms
64 bytes from 172.19.166.68: seq=6 ttl=63 time=25.455 ms
64 bytes from 172.19.166.68: seq=7 ttl=63 time=19.186 ms
64 bytes from 172.19.166.68: seq=8 ttl=63 time=29.319 ms
64 bytes from 172.19.166.68: seq=9 ttl=63 time=19.027 ms
64 bytes from 172.19.166.68: seq=10 ttl=63 time=23.557 ms
...
64 bytes from 172.19.166.68: seq=298 ttl=63 time=25.580 ms
64 bytes from 172.19.166.68: seq=299 ttl=63 time=18.591 ms
64 bytes from 172.19.166.68: seq=300 ttl=63 time=18.340 ms
64 bytes from 172.19.166.68: seq=301 ttl=63 time=34.543 ms
64 bytes from 172.19.166.68: seq=302 ttl=63 time=24.987 ms
64 bytes from 172.19.166.68: seq=303 ttl=63 time=18.314 ms
64 bytes from 172.19.166.68: seq=304 ttl=63 time=26.889 ms
64 bytes from 172.19.166.68: seq=305 ttl=63 time=31.666 ms
64 bytes from 172.19.166.68: seq=306 ttl=63 time=18.661 ms

--- 172.19.166.68 ping statistics ---
307 packets transmitted, 307 packets received, 0% packet loss
round-trip min/avg/max = 9.624/24.367/44.545 ms
```

Figure 11: Results of a ping from the OBU to the ES MEC

```
root@imx6qdlhmcu:~# ping 172.19.166.69
PING 172.19.166.69 (172.19.166.69): 56 data bytes
64 bytes from 172.19.166.69: seq=0 ttl=63 time=37.770 ms
64 bytes from 172.19.166.69: seq=1 ttl=63 time=37.502 ms
64 bytes from 172.19.166.69: seq=2 ttl=63 time=37.340 ms
64 bytes from 172.19.166.69: seq=3 ttl=63 time=39.311 ms
64 bytes from 172.19.166.69: seq=4 ttl=63 time=36.098 ms
64 bytes from 172.19.166.69: seq=5 ttl=63 time=26.825 ms
64 bytes from 172.19.166.69: seq=6 ttl=63 time=26.641 ms
64 bytes from 172.19.166.69: seq=7 ttl=63 time=11.220 ms
64 bytes from 172.19.166.69: seq=8 ttl=63 time=28.009 ms
64 bytes from 172.19.166.69: seq=9 ttl=63 time=26.139 ms
64 bytes from 172.19.166.69: seq=10 ttl=63 time=9.944 ms
...
64 bytes from 172.19.166.69: seq=294 ttl=63 time=17.752 ms
64 bytes from 172.19.166.69: seq=295 ttl=63 time=27.068 ms
64 bytes from 172.19.166.69: seq=296 ttl=63 time=26.769 ms
64 bytes from 172.19.166.69: seq=297 ttl=63 time=27.585 ms
64 bytes from 172.19.166.69: seq=298 ttl=63 time=21.652 ms
64 bytes from 172.19.166.69: seq=299 ttl=63 time=21.283 ms
64 bytes from 172.19.166.69: seq=300 ttl=63 time=26.186 ms
64 bytes from 172.19.166.69: seq=301 ttl=63 time=15.424 ms
64 bytes from 172.19.166.69: seq=302 ttl=63 time=20.796 ms
64 bytes from 172.19.166.69: seq=303 ttl=63 time=24.995 ms

--- 172.19.166.69 ping statistics ---
304 packets transmitted, 304 packets received, 0% packet loss
round-trip min/avg/max = 9.822/23.825/42.829 ms
```

Figure 12: Results of a ping from the OBU to the MQTT in a VM hosted by the ES MEC

In addition, Figure 13 provides the data rate from the OBU to the MEC in both UL and DL.

```
TCP protocol, 30 secs of UPLOAD data
-1 socket = 35.78 Mbps (average of 5 speed tests)
-2 sockets = 78.54 Mbps (average of 5 speed tests)
-5 sockets = 77.86 Mbps (average of 5 speed tests)
-10 sockets = 77.26 Mbps (average of 5 speed tests)
-20 sockets = 77.2 Mbps (1 speed test)

TCP protocol, 30 secs of DOWNLOAD data
-1 socket = 58.16 Mbps (average of 5 speed tests)
-2 sockets = 100.34 Mbps (average of 5 speed tests)
-5 sockets = 181.2 Mbps (average of 5 speed tests)
-10 sockets = 186 Mbps (average of 2 speed test)
-20 sockets = 185 Mbps (1 speed test)
```

Figure 13: Speed tests from the OBU to the ES MEC

These checks in every OBU/RSU were set as mandatory before starting any test to ensure that the test is executed using 5G. The verification tests, which were performed in the real environment (A55 in the ES side) to characterize the real scenarios where the full trials are being deployed show also good values in accordance to the range -44 dBm (best value) and -140 dBm (worst value) provided by the modem provider –(Quectel) for the RSRP (Figure 14) and the latencies (Figure 15) are in required range, fulfilling the initial US requirements (see Table 15 in D2.5).

Figure 14: RSRP in dBm values in the A55 motorway (ES side)

Latency scatter

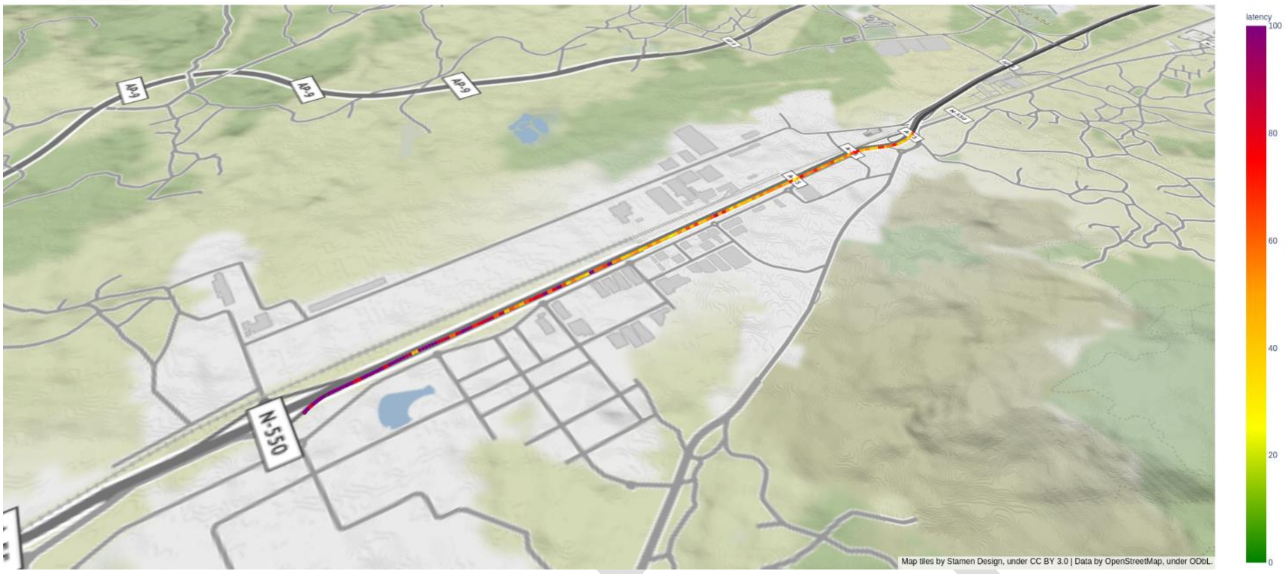

Figure 15: Latency in ms values in the A55 motorway (ES side)

The next sub-sections show the particularities of every US during the verification phase.

3.1.1 US#1.1.a: Complex manoeuvres in cross-border settings: lane merge for automated vehicles (LaneMerge)

3.1.1.1 Verification process overview

The verification of lane merge US has been carried out firstly in CTAG test track (Figure 16) with the vehicles and OBUs provided by CTAG, the radar and RSU by CTAG, the ES MEC provided by Nokia ES (where the MQTT broker was hosted by CTAG) and under the private 5G network provided by Telefónica and managed by Nokia ES. The tests have been focused on testing: the proper operation of the CCAM functions integrated in the vehicles; the connectivity of OBUs, RSU, and MEC; the logging capabilities of the OBUs, RSU, and MEC; and the current configuration of the 5G network.

After that, the lane merge was moved to the real environment (A55 motorway in the ES side and the ES-PT border) to perform the final adjustments at high speed, check the PT network, include the PT OBU by IT to check the interoperability, and also the OBUs by ISEL to stress the network.

Figure 16: Design of a lane merge at CTAG's test tracks

A complete description of this US and all the actors involved can be found in D3.4 [9]. The scope of this verification has been to check how a vehicle is able to perform a lane merge existing connected and non-connected vehicles on the main road, the first ones identified by means of the CAM messages and the latter by the CPM messages of the radar. All these messages are managed by the MQTT brokers hosted on the ES and PT interconnected MECs.

3.1.1.2 Main results

Table 5 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.1.1):

Table 5: Verification results for the Lane Merging user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
Infrastructure related issues	6	0	0	0	100 %
UE related issues	24	0	0	0	100 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	3	0	0	0	100 %
Network related issues	11	0	0	0	100 %
Subtotal: functional issuess	35	0	0	0	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	5	0	0	0	100 %
Total	**41**	**0**	**0**	**0**	**100 %**

Note: All the data flows involving ETSI messages are being analysed in the same way, so the more detailed explanation of the results is provided for the CAM messages in the overtaking chapter (3.1.2), with results comparable to the ones for the CPM messages in lane merge (3.1.1) and the DENM messages in cooperative automated (3.1.3).

The verification of the lane merge is focused on the generation and transmission of CPM messages since the analysis with the CAM messages for the connected vehicles is the same as the one in the overtaking (see 3.1.2).

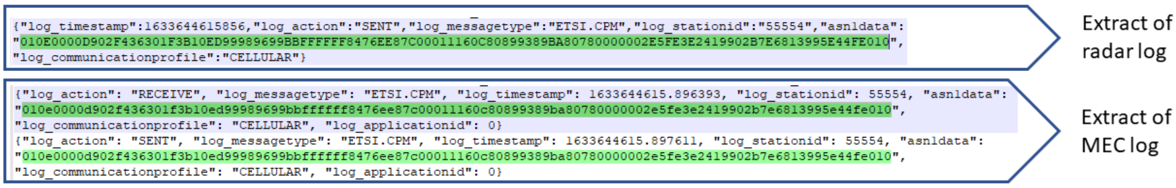

Figure 17: Snapshot of radar and MEC logs at the application layer

The radar was installed and calibrated in the CTAG's test tracks to test its capability to detect objects in movement in the lanes where the maneuver is going to be performed. It was also tested how the radar sent the information to the RSU to build the corresponding CPM message that will be managed by the MQTT. In this way, Figure 17 shows at the application layer one CPM message sent by the RSU and subscribed/published in the ES MEC.

3.1.1.3 Next steps

The full trials in the real environment were already done (October 7 and November 3, 2021) on the ES side (A55 motorway). The verification activities are in Q1 2022 in the border ES-PT (A55 motorway in the New Bridge) in order to check the impact of the roaming and handover processes on the exchange of CAM and CPM messages by the MECs. It is also expected to run this US on the PT side (A28 motorway), once the gNB is completely operative.

3.1.2 US#1.1.b: Complex manoeuvres in cross-border settings: automated overtaking (Overtaking)

3.1.2.1 Verification process overview

The activities of verification of overtaking US have been carried out in CTAG test track (Figure 18) with the vehicles and OBUs provided by CTAG, the ES MEC provided by Nokia ES (where the MQTT broker is hosted by CTAG) and under the private 5G network provided by Telefónica and managed by Nokia ES (Figure 18). The tests have been focused on testing: the correct operation of the CCAM functions integrated in the vehicles; the connectivity of OBUs and MEC; the capabilities of logging of the OBUs and MEC; and the current configuration of the 5G network.

The verification tests in the real environment (A55 on the ES side and the border ES-PT) were used to adapt the CAM functionalities to the high speed, test the PT network, integrate the PT OBU by IT to check the interoperability and the OBUs by ISEL for network stressing.

Figure 18: Verification of Overtaking in CTAG's test tracks

A complete description of this US and all the actors involved can be found in D3.4 [9]. The scope of this verification has been to check at the national level (ES side) how a vehicle is able to perform an overtaking manoeuvre with the help of the CAM messages exchanged with other vehicles on the road by means of an MQTT server on the MEC.

3.1.2.2 Main results

Table 6 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.1.2):

Table 6: Verification results for the Overtaking user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
UE related issues	18	0	0	0	100 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	3	0	0	0	100 %
Network related issues	11	0	0	0	100 %
Subtotal: functional issues	29	0	0	0	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	5	0	0	0	100 %
Total	**35**	**0**	**0**	**0**	**100 %**

The working of the overtaking is based on the exchange of CAM messages by all the vehicles involved in the manoeuvre by means of the MQTT brokers hosted in the MECs. In this way, the in-vehicle algorithm in the EGO vehicle is aware of the GPS positions and speeds of the vehicles on the road to perform the overtaking. The messages sent by the vehicles and published in the MEC in UL and sent by the MEC to the EGO vehicle in DL are logged at the three different layers: at the application level by using a proprietary format, at the network level with TCPDump (Figure 19) and at the radio level with the proprietary tool of the modem.

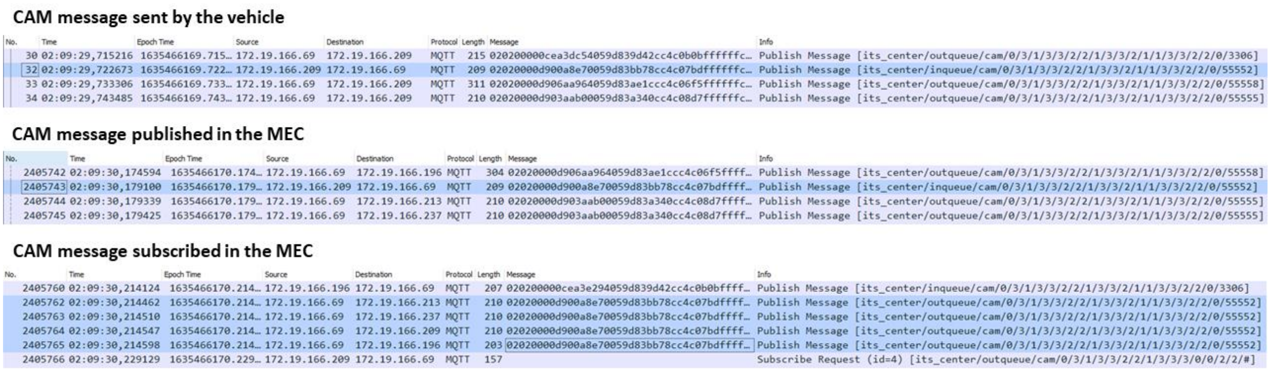

Figure 19: CAM message sent from the vehicle to be published/subscribed in the MEC at the network layer

These logs in the two ends of the communication are the sources to obtain the indicators to measure the 5G capabilities of our network. Figure 20 and Figure 21 show latency values in the expected range for UL and DL showing, in addition, a good synchronization between devices.

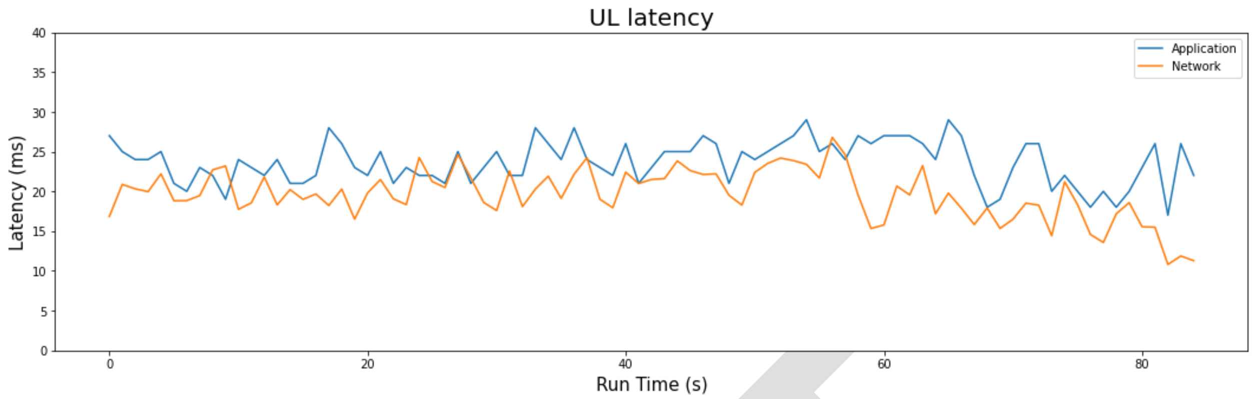

Figure 20: Latency of the CAM messages at the application and network level in UL

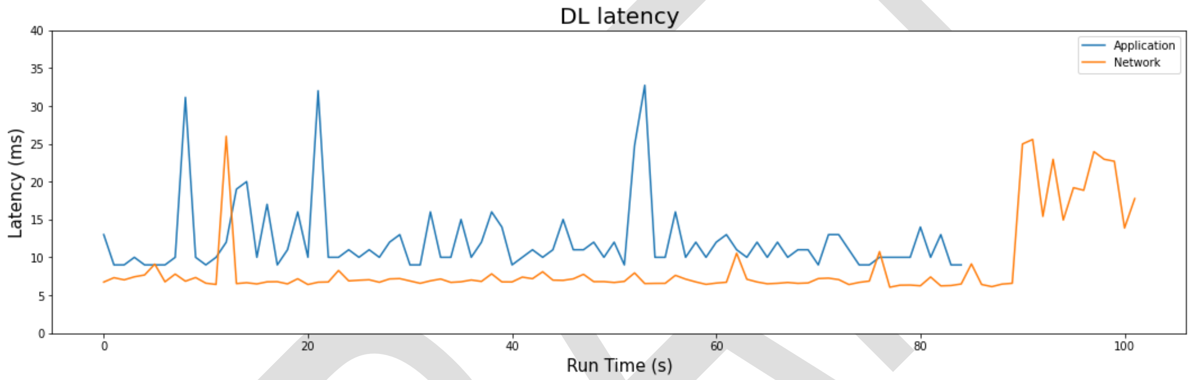

Figure 21: Latency of the CAM messages at the application and the network level in DL

The tools developed to convert the local logs into the common data format were also checked validating in addition the proper collection of the complete set of data (Figure 22).

timestamp	senderstationid	receiverstationid	longitude	latitude	senderspeed	receiverspeed	flowdirection	communicationprotocol	communicationprofile	ratmode	messagetype	datarate	e2elatency	messagestx	messagesrx
1635992346985	3302	3331	-8.625576	42.147117	10.71	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00528	24	10	10
1635992347986	3302	3331	-8.625568	42.147029	10.31	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00528	38	10	10
1635992348985	3302	3331	-8.625552	42.146863	9.59	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00528	23	10	10
1635992349887	3302	3331	-8.625552	42.146863	9.59	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.004912	25	9	9
1635992350985	3302	3331	-8.625543	42.146773	9.25	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.004112	22	9	9
1635992351986	3302	3331	-8.625535	42.146687	9.61	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00528	22	10	10
1635992352986	3302	3331	-8.62552	42.146508	10.73	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00528	22	10	10
1635992353985	3302	3331	-8.62552	42.146508	10.73	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00528	23	10	10
1635992354985	3302	3331	-8.625512	42.146417	11.14	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00528	23	10	10
1635992355986	3302	3331	-8.625503	42.146318	11.54	0	UL	MQTT	CELLULAR	5G NR	ETSI.CAM	0.00448	23	10	10

Figure 22: Common data format for the UL of CAM messages at the application layer

3.1.2.3 Next steps

The full trials started on the ES side (A55 motorway) last 2021 (September 28 and October 28). The efforts were consecutively focused on the final adjustments for performing the trials on the border between ES and PT (A55 motorway in the New Bridge) by Q1 2022, especially at the interconnection network level measuring the impact of the roaming and handover processes.

3.1.3 US#1.5: Automated shuttle driving across borders: cooperative automated system (CoopAutom)

3.1.3.1 Verification process overview

The activities of verification of the Cooperative Automated Operation US have been carried out in CTAG test track, with the shuttle and OBU provided by CTAG, the cooperative collision system provided by CTAG, the ES MEC provided by Nokia ES with the MQTT broker by CTAG, and under the private 5G network provided by Telefónica and managed by Nokia ES (Figure 23). The tests have been focused on testing: the functionalities of the shuttle, OBU, RSU and MEC; the capabilities of logging of the OBU, RSU, and MEC; and the current configuration of the 5G network.

Besides the trials in the test track, some trials were already done in real testing sites, namely the Old Bridge between Tui and Valença.

Figure 23: Verification of Cooperative Automated System in CTAG's test tracks

A complete description of this US and all the actors involved can be found in D3.4 [9]. The scope of this verification has been to check at the national level (ES side) how the shuttle is able to perform a stopping manoeuvre based on the DENM messages received from the collision detection system through the MQTT service on the MEC.

3.1.3.2 Main results

Table 7 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.1.6):

Table 7: Verification results for the CoopAutom user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	9	0	1	0	100 %
Infrastructure related issues	6	0	3	0	100 %
Other end user devices	4	0	1	1	75 %
UE related issues	28	0	1	1	95 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	3	0	0	0	100 %
Network related issues	11	0	0	0	100 %
Subtotal: functional issues	39	0	1	1	96 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	5	0	0	0	100 %
Total	**45**	**0**	**1**	**1**	**97 %**

The maturity of the development is such that the CCAM functions are properly working, making use of the 5G connectivity and MEC at the national level. The VRU android app is working as intended, successfully sending CAM messages to the broker. The tests revealed some issues with the sending frequency (occasionally inconsistent and lower than required) but they have been addressed.

A pedestrian detection system will be installed, composed of a pedestrian radar supplied by Siemens connected to a roadside unit from CTAG. We have been working on the integration between the two equipment's that is now complete. The next step is to install the system and run the final tests on the site in the Old Bridge.

3.1.3.3 Next steps

Further trials are planned for the first quarter of 2022 at the Old Bridge site. These will not only include CTAG's RSU, but also the Siemens RSU (pedestrian radar) and CCG VRU app.

3.1.4 US#3.1.a: Complex manoeuvres in cross-border settings: HD Maps (HDMapsVehicle)

3.1.4.1 Verification process overview

The activities of verification of HDMapsVehicle US have been carried out in CTAG test track with the vehicles, OBUs, and server provided by CTAG and under the private 5G network provided by Telefónica and managed by Nokia ES (Figure 24). The tests have been focused on testing: the functionalities of the vehicles, OBUs and server; the capabilities of logging of the OBUs and server; and the current configuration of the 5G network.

In this US, the MEC is used for monitoring purposes (to track the vehicles using their CAM messages sent) but this functionality is out of the scope of this verification because it was already tested for Advanced Driving USs.

Figure 24: Verification of HDMapsVehicle in CTAG´s test tracks

A complete description of this US and all the actors involved can be found in D3.4 [9]. The scope of this verification has been to check at the national level (ES side) how a vehicle is able to record a dynamic event on the road with the sensors onboard and upload this large file using the 5G network to the ES server. At a second stage, it is tested how this file is converted into the updated HD Maps and downloaded to another vehicle to be able to drive autonomously by taking the new event into account.

3.1.4.2 Main results

Table 8 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.3.1):

Table 8: Verification results of the HDMapsVehicle user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
External servers	5	0	3	0	100 %
UE related issues	23	0	0	0	100 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	3	0	0	0	100 %
Network related issues	11	0	0	0	100 %
Subtotal: functional issues	34	0	0	0	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	5	0	0	0	100 %
Total	**40**	**0**	**0**	**0**	**100 %**

The verification of the HDMaps started with the generation of the file with the dynamic event information captured by the sensors data. This file was successfully recorded using the proprietary ADTF file and the OBU was also able to upload this file to the server. Figure 25 shows the application logging file where the uploading progress can be checked. At the second stage, this information is dumped on the online HDMaps in order to update it and come back to the vehicles on the road.

```
1633037173674 STARTING: 0 of: /home/duser/logs/HDMaps_Folders/5GMOBIX_LOG_e5789322_20210930231605_01.dat -> /C:/5gmobix/hdmapsdata/5GMOBIX_LOG_e5789322_20210930231605_01.dat Size: 4243 MB
1633037173798 File 5GMOBIX_LOG_e5789322_20210930231605_01.dat Package size trasmited: 31 KB. Already uploaded: 31 KB
1633037173830 File 5GMOBIX_LOG_e5789322_20210930231605_01.dat Package size trasmited: 31 KB. Already uploaded: 63 KB
1633037173843 File 5GMOBIX_LOG_e5789322_20210930231605_01.dat Package size trasmited: 31 KB. Already uploaded: 95 KB
1633037173855 File 5GMOBIX_LOG_e5789322_20210930231605_01.dat Package size trasmited: 31 KB. Already uploaded: 127 KB
1633037173873 File 5GMOBIX_LOG_e5789322_20210930231605_01.dat Package size trasmited: 31 KB. Already uploaded: 159 KB
1633037173881 File 5GMOBIX_LOG_e5789322_20210930231605_01.dat Package size trasmited: 31 KB. Already uploaded: 190 KB
1633037173890 File 5GMOBIX_LOG_e5789322_20210930231605_01.dat Package size trasmited: 31 KB. Already uploaded: 222 KB
```

Figure 25: Snapshot of vehicle log for the uploading of sensors data at the application layer

Figure 26 shows the throughput of the uploading process with values in agreement with the target values.

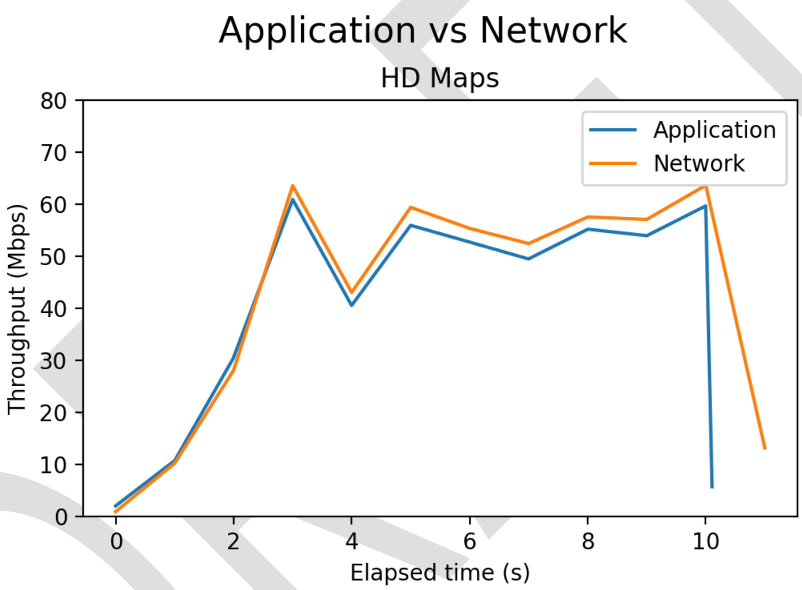

Figure 26: Throughput for the uploading of the file

3.1.4.3 Next steps

The full trials on the ES side (A55 motorway) were already executed (September 30, 2021) and it is planned to run the ones in the ES-PT border (A55 motorway, New Bridge) by Q1 2022. The pending points are the ones linked to the network interconnection which means the transfer of the JSON file between the ES and PT servers with the sensors' information.

3.1.5 US#3.1.b: Public transport: HD Maps (HDMapsPublicTransport)

3.1.5.1 Verification process overview

The verification of the HDMapsPublicTransport user story is very similar to the HDMapsVehicle user story (Section 3.1.4) but, in this case, the vehicle recording the dynamic event is the ALSA bus (Figure 27). The ALSA bus has been moved to CTAG facilities to finish the integration activities, which include both the sensors (camera and LiDAR) and the OBU provided by CTAG and run the US in the ES 5G environment.

Figure 27: Tests in CTAG's test tracks in HDMapsPublicTransport US

A complete description of this US and all the actors involved can be found in D3.4 [9]. The scope of this verification has been to check at the national level (ES side) how the ALSA bus is able to record a dynamic event on the road with the sensors onboard and upload this large file using the 5G network to the ES server. At a second stage, it is tested how this file is converted into the updated HD Maps and downloaded to another vehicle to be able to drive autonomously by taking the new event into account.

3.1.5.2 Main results

Table 9 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.3.1):

Table 9: Verification results of the HDMapsPublicTransport user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
External servers	5	0	3	0	100 %
UE related issues	23	0	0	0	100 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	3	0	0	0	100 %
Network related issues	11	0	0	0	100 %
Subtotal: functional issues	34	0	0	0	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	5	0	0	0	100 %
Total	**40**	**0**	**0**	**0**	**100 %**

The maturity of the development is such that the CCAM functions are properly working, making use of the 5G connectivity and server at the national level.

3.1.5.3 Next steps

It is planned to start running the full trials by Q1 2022 in the ES-PT border (New Bridge). The pending points are the ones linked to the network interconnection.

3.1.6 US#4.1: Automated shuttle driving across borders: remote control (RCCrossing)

3.1.6.1 Verification process overview

Remote Control US has been verified in CTAG using the autonomous shuttle and the OBU provided by CTAG, the virtual glasses by Nokia ES (to be used by the remote driver in the cockpit in CTAG), the ES MEC provided by Nokia ES and under the private 5G network provided by Telefónica and managed by Nokia ES (Figure 28).

Figure 28: Verification of Remote Control in CTAG

The first objective of the verification has been to evaluate the impact on the safety of the latency between the image received in the glasses and the driving at different speeds. Figure 29 shows the GPS position of the vehicle when driving with a latency of 150ms showing good results with only minor deviations in the curves.

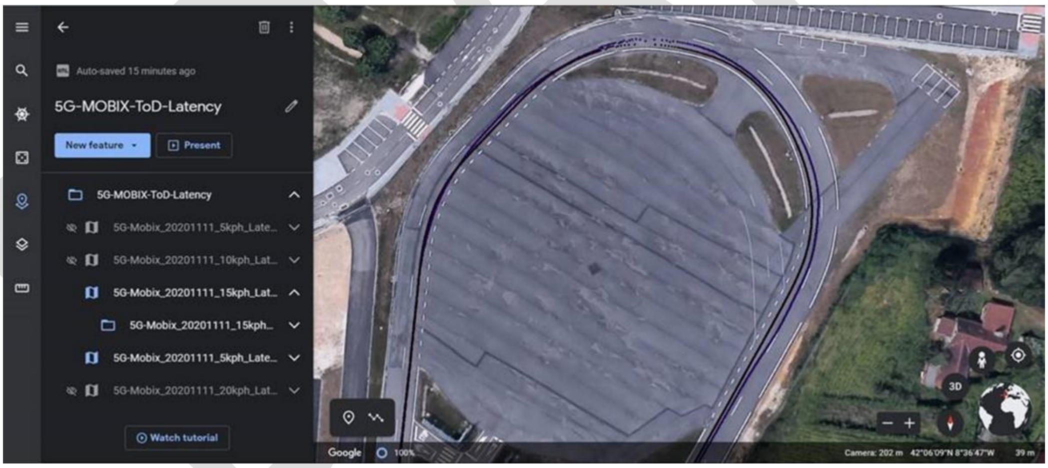

Figure 29: Latency study in Remote Control at CTAG's test tracks

A complete description of this US and all the actors involved can be found in D3.4 [9]. The verification has been focused on testing the remote driving, using as reference the streaming of the camera received in the virtual glasses, at the national level (ES side) under the 5G network.

3.1.6.2 *Main results*

Table 10 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.3.1):

Table 10: Verification results of the RCCrossing user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	8	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	22	0	0	0	100 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	3	0	0	0	100 %
Network related issues	11	0	0	0	100 %
Subtotal: functional issues	33	0	0	0	100 %
Privacy and security issues	2	0	0	0	100 %
Logging related issues	5	0	0	0	100 %
Total	**41**	**0**	**0**	**0**	**100 %**

The development of the US is in a very advanced situation and the CCAM functions are working in the 5G environment provided by Telefónica and Nokia ES. Tests with "partly" and "not tested" results are mainly linked to the lack of stability of the handover functionality.

The following aspects have been verified during the tests performed in July and October 2021:

[1] Video frame rendering rate is appropriate for remote driving

This means that we need to measure both at the encoding point of transmission and in the Head-Mounted Device (HMD) in which the video is being decoded:

A specific tool has been developed in order to pass the gstreamer video logs issued at the Jetson Xavier board and the ones decoded in the PC which is connected to the HMD. The results are as follows:

Table 11: Video frame rendering rate for remote driving

	ENCODING	DECODING			
	Encoding Stream 1	Decoding Stream 1 (L)	Decoding Stream 2 (F)	Decoding Stream 3 (R)	Decoding Stream 4 (B)
StreamID	000001FCDF079D40	000001FCDF079440	000001FCDF079A40	000001FCDF079D40	000001FCDF079140
Elapsed Time(s)	245,7949	2691,3430	2691,3217	2691,0145	2690,4836
Encoded Frames	7263	56206	56475	54965	20272
Average Instant FPS	32,3990	39,2626	40,0678	39,1559	12,8817
Average Overall FPS	29,5490	20,8840	20,9841	20,4254	7,5347
Dropped Frames (Abs)	109	4036	3804	5068	13483
Dropped Frames (%)	1,5032	7,1822	6,7373	9,2205	66,5124
Presented Frames(%)	98,4968	92,8178	93,2627	90,7795	33,4876

The conclusions are that it is expected that every encoder in the sender side is able to encode something close to 30 fps (Frames per second). We tested that the actual figures are 29,54 fps which means an average drop of 1,5% frames. In the decoder side the Oculus Quest2 HMD operates at a 90Hz refresh rate, meaning that if decoding four simultaneous streams is required, it will be able to render frames at 90/4 = 22.5 fps approximately in each rendered shader surface. The results depict that the gstreamer is able to provide the renderer with almost 21 fps which is pretty close to the maximum and implies 1 frame loss every second. This amount of loss frame ratio is appropriate for driving at speed of less than 20 km/h.

[2] Round Trip Time is less than 100 ms in UDP control commands issued from the cockpit to the vehicle (HMCU)

Logs have been captured at the Cockpit control application, and include the Geo located data of the Old Bridge Scenario in Tui in the border. The green dots mean latencies under 50 ms, the red dots are for 50-100 ms latencies and black dots are for 100-150 ms latencies. All the bridge path has low latency measurements except when we move close to the buildings outside the bridge. In this area, there is no problem when the shuttle is driving at low speeds.

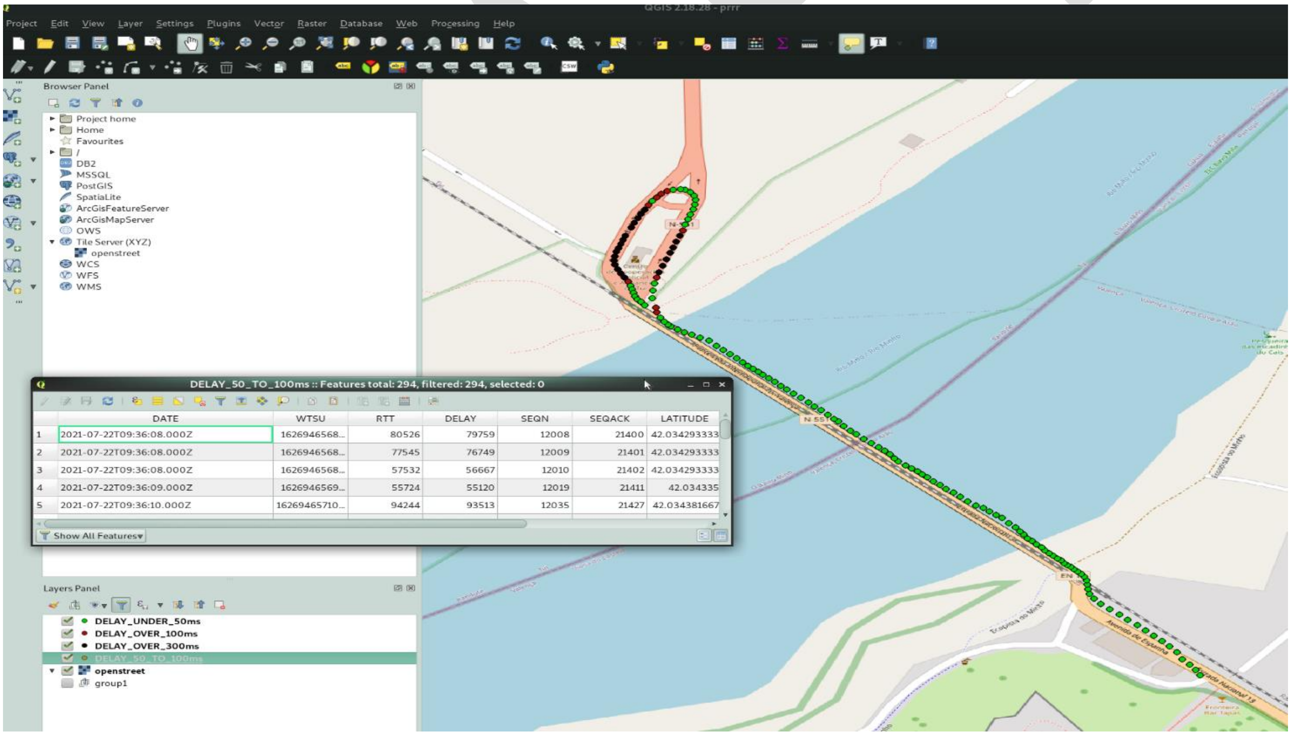

Figure 30: QGIS Visualization of Latencies in Old Bridge

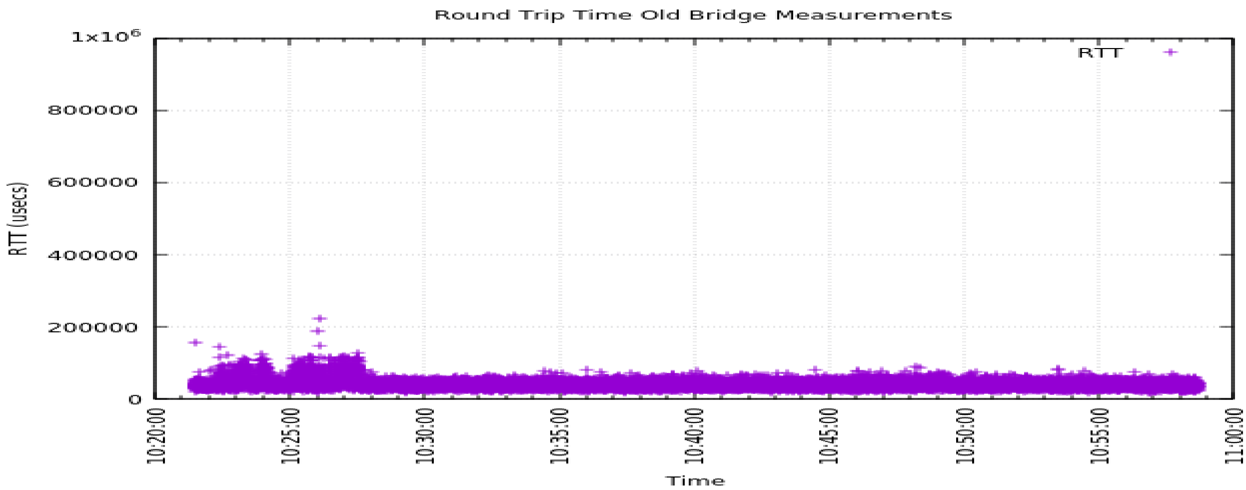

Figure 31: Round Trip Time Latency in Remote Driving

The Round-Trip Time (RTT) measurements are almost 100% under 100 ms, which are appropriate for remote driving as the commands are asynchronously issued every 100 ms and should be acknowledged in the time frame. (Please note that the graph has a microseconds scale in the Y axis).

[3] Uplink and downlink latencies in the MEC-HMCU path are as expected in a 5G Connection

Logs have been captured both in MEC and CTAG HMCU onboard unit. It is important to remark the fact that 5G-MEC has a near 1ms time synchronization. In the case of HMCU via GPS and in the MEC case using low stratum NTP server, we can thus conclude that both measurements are synchronized in time with a precision of about 1ms.

A sample of the captured logs is shown below:

(1) MEC TO RSU trace

1634891060481,0.1,,,,,,,,,DL,NR_NSA,UDP,PROPRIETARY,,,,,,0,1596,1596

(2) RSU reception +7ms (**1634891060488 – 1634891060481**)

1634891060488 ----> Receiving from MEC: {"TYPE":"CMD","CAR":"CARSIM","SEQN":1596,"WTSU":1634891062202292,"SPEED":0,"STEE":-458.7450000000019,"BRAKE":0,"DEL1":0,"MEC1":"10.8.0.1:5001","DEL2":0,"MEC2":"10.8.0.1:5001","MEC_COCKPIT":"10.8.0.1:5001","GEAR":1,"BUTTON_L2":0,"B....

(3) RSU execute control in CAN and ACKs Message with telemetry +3ms (**1634891060491 – 1634891060488**)

1634891060491 <--- Sending to RD Server: {"MEC1":"10.8.0.1:5001","BRAKE":0,"MEC2":"10.8.0.1:5001","BUTTON_R2":0,"ACCY":0,"ACCZ":0,"SEQN":1596,"ACCX":0,"TLIGHT":2,"SPEED":0:0,"WTSU":1634891062202292,"BUTTON_L2":0,"TYPE":"CMD_ACK","REAL_SPEE":0,"TAKEOVER":0,"RE

(4) MEC RECEIVES ACK from RSU and forwards to COCKPIT +19ms (**1634891060510 – 1634891060491**)

1634891060510,0.1,,,,,-8.613827292,42.102671016,,0,UL,NR_NSA,UDP,PROPRIETARY,,,,,-1692267,1596,1596

The radio uplink and downlink latencies are depicted in Figure 32 for the Old Bridge tests.

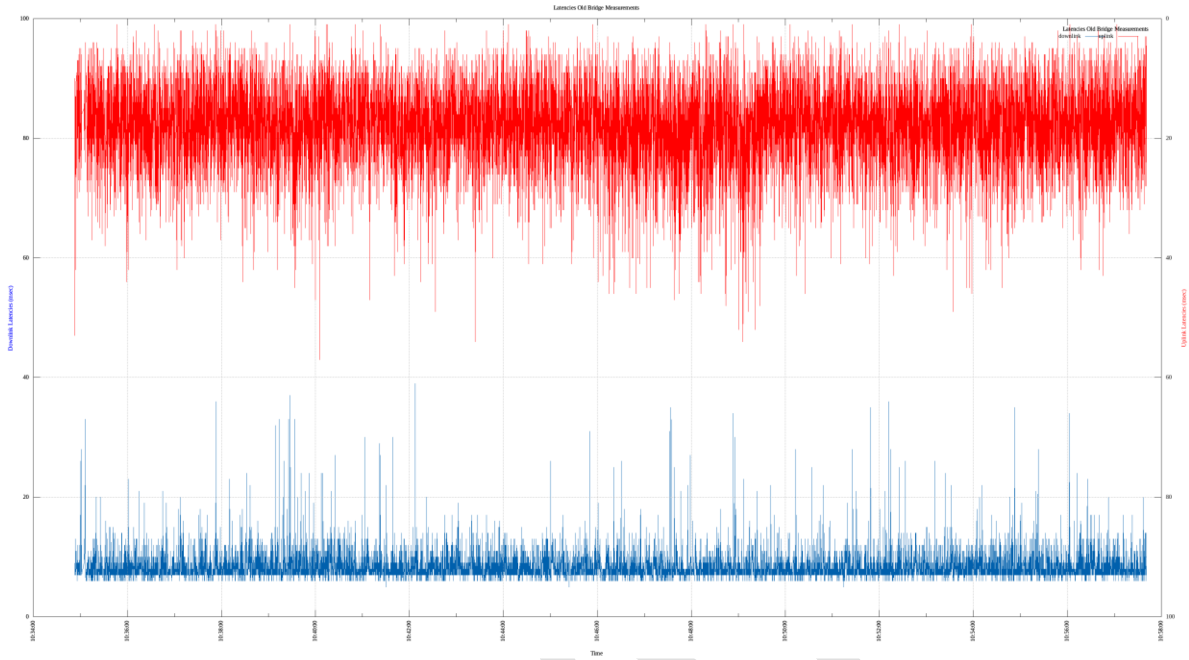

Figure 32: RSU to MEC downlink and uplink latencies

The results show latencies under 20 ms for downlink with an average under 10 ms (in blue) and uplink latencies are mostly under 40ms (in red) with an average line of 20ms. (Please notice the Y axis is reversed for uplink measurements for a more compact presentation.)

3.1.6.3 Next steps

Tests in the real environment with handover functionality are planned by Q1 2022 in the cross-border (Old Bridge) with previous tests on CTAG private track. These tests will be performed using the Home Routed handover configuration. Local breakout tests are planned in a subsequent phase using the local IP address of the neighbour network and forwarding the VPN tunnels from one MEC to the other so that IP addresses inside VPN are the same regardless the MEC to which the RSU is connected.

3.1.7 US#5.1: Public transport: HD media services and video surveillance (MediaPublicTransport)

3.1.7.1 Verification process overview

The tests have been performed in close collaboration between CTAG and ALSA. The ALSA bus has been moved to CTAG facilities to finish the integration activities and test the US under the private 5G network provided by Telefónica and managed by Nokia ES (Figure 33).

The verification in this US has been performed for the two use cases under this US: Multimedia Service for passengers and 4k streaming.

Figure 33: Tablets in ALSA bus employed in the MediaPublicTransport user story

A complete description of this US and all the actors involved can be found in D3.4 [9]. During the verification, the Multimedia Server by ALSA was able to send the multimedia content to the 60 tablets on the bus under the ES network, logging this communication at the network level. On the other hand, the ALSA bus was able to send in real time the 4k streaming from a camera onboard to the ALSA Control Center, logging also at the network level.

3.1.7.2 Main results

Table 12 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.3.1):

Table 12: Verification results for the MediaPublicTransport user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	6	0	0	0	100 %
OBU related issues	6	0	0	0	100 %
External servers	3	0	1	0	88 %
UE related issues	15	0	1	0	97 %
5G network related issues	3	0	0	0	100 %
Network handover related issues	0	0	2	0	50 %
Network related issues	3	0	2	0	80 %
Subtotal: functional issues	18	0	2	0	93 %
Privacy and security issues	2	0	0	0	100 %
Logging related issues	2	0	2	1	60 %
Total	**36**	**0**	**5**	**1**	**88 %**

Figure 34 shows the throughput values for the different tests carried out at the CTAG test tracks to check the quality of the image and the 5G performance in four different tests:

- Test #1: video 4k at 25 fps | camera at 7 Mbps with MTU 1000
- Test #2: video at 25 fps | camera at 5 Mbps with MTU 1000
- Test #3: video at 30 fps | camera at 5 Mbps with MTU 1000
- Test #4: video at 30fps | camera at 6 Mbps with MTU 900

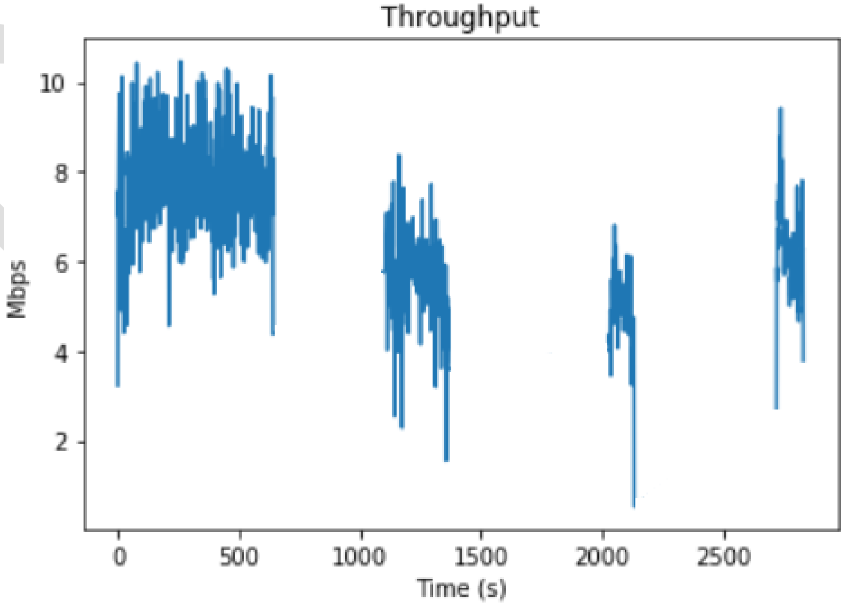

Figure 34: Throughput values for different configurations of the 4k streaming

Figure 35 shows the throughput for the Multimedia Service use case in good agreement with the expected results.

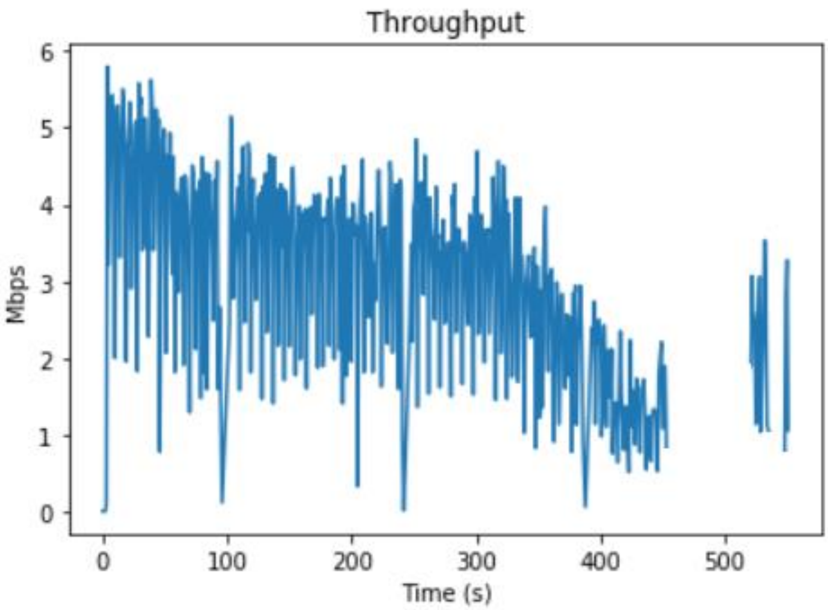

Figure 35: Throughput values of the multimedia server

In both use cases, these values were obtained from the pcap (packet capture) files logged at the bus and the corresponding servers.

3.1.7.3 Next steps

Tests in the real environment are planned by Q2 2022 in the regular route of the bus between Vigo and Porto, which also goes through the cross-border location. Current activities are focused on checking the synchronization between devices and developing the tools to create the common data format and extracting the corresponding KPIs.

3.2 Greece-Turkey Cross-Border Corridor

3.2.1 US#2.1.a: Platooning with "See What I See" functionality in cross-border settings (SeeWhatISee)

3.2.1.1 Verification process overview

The verification of the proper functionality of all the components of the SeeWhatISee user story has been performed by ICCS in their premises in Athens and in Cosmote's facilities, with a relevant 5G-testbed (5G EVE platform). These tests have also verified the correct communication and functionality of the application devices (server and clients) that will be used in this US (see 5G-MOBIX Deliverable D3.4 [9]), which were all 4developed/updated/deployed by ICCS.

Due to the COVID-19 travel restrictions, which are in effect in Greece since October 2020, the integration of the ICCS developed SeeWhatISee application with the Ford truck and the 5G networks of Cosmote and Turkcell could not go ahead as planned, and be performed at the Ford facilities in Eskisehir (Turkey) and at the cross-border site. To cope with this unforeseen circumstance, most of the integration tests are currently performed using a substitute but identical 5G network located in Cosmote's facilities in Athens. As a result, the basic local tests and the confirmation of integration tests have been performed. In this way, a big part of the COVID-19 impact has been absorbed and will allow for the successful initiation of the SeeWhatISee trials at the borders, according to the updated trial planning. The final verification of the SeeWhatISee took place the final cross-border tests in the GR-TR CBC TS (01/03/2022). In this area, both Home Routing and Local Breakout scenarios will be tested while making comparisons between a cloud server and the GR edge server. It is pointed out that the specific user story can be completely worked with one edge server giving the required results.

3.2.1.2 Main results

The detailed checklist of all the verification and integration tests performed for the SeeWhatISee US is presented in Annex 2 (Section 6.2.1). The remainder of this section provides some overview information regarding the circumstances of these tests and their outcome.

Table 13: Verification results of the SeeWhatISee user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	7	0	0	0	100 %
OBU related issues	3	0	0	0	100 %
Infrastructure related issues	2	0	0	0	100 %
External servers	1	0	0	0	100 %
Other end user devices	6	0	0	0	100 %
UE related issues	19	0	0	0	100 %
5G network related issues	6	0	0	0	100 %
Network handover related issues	1	0	0	0	100 %
Network related issues	7	0	0	0	100%
Subtotal: functional issues	26	0	0	00	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	6	0	0	0	100 %
Total	**33**	**0**	**0**	**0**	**100 %**

Integration/verification of SeeWhatISee application with 5G network and Edge servers

The ICT-17 5G-EVE testbed located in Cosmote premises in Athens is used to verify the correct integration of the SeeWhatISee application with the 5G network and the capability to send and receive messages from the OBU participating in this US. ***The 5G-EVE testbed is also built by Ericsson and is identical to the 5G***

network deployed at the GR-TR borders. The SeeWhatISee application was successfully integrated with the COSMOTE 5G Network and the GR edge server. In addition, the SWIS application client devices were successfully integrated with IMEC OBUs in the FORD trucks. In the GR-TR CBC area, both Home Routing and Local Breakout scenarios will be tested making comparisons between a cloud and the GR edge server.

Leader Truck

```
protonot@leader:~/workspace/swis_leader$ traceroute 195.148.127.155
traceroute to 195.148.127.155 (195.148.127.155), 30 hops max, 60 byte packets
1 _gateway (192.168.221.1) 0.842 ms 0.721 ms 0.499 ms
2 ppp-94-67-142-173.home.otenet.gr (94.67.142.173) 104.856 ms 104.769 ms 104.761
ms
3 ppp-94-67-142-174.home.otenet.gr (94.67.142.174) 94.561 ms 94.588 ms 98.551 ms
4 ppp-94-67-142-193.home.otenet.gr (94.67.142.193) 104.317 ms 104.282 ms 104.231
ms
5 79.128.228.144 (79.128.228.144) 104.261 ms 104.266 ms 104.226 ms
6 62.75.3.69 (62.75.3.69) 104.062 ms 99.813 ms 103.441 ms
7 62.75.6.222 (62.75.6.222) 142.118 ms 62.75.14.146 (62.75.14.146) 147.490 ms
62.75.14.150 (62.75.14.150) 147.447 ms
8 195.66.225.24 (195.66.225.24) 152.601 ms 152.649 ms 152.607 ms
9 de-ffm.nordu.net (109.105.97.79) 158.305 ms 158.295 ms 158.314 ms
10 de-hmb.nordu.net (109.105.97.104) 168.175 ms 172.281 ms 172.174 ms
11 99.83.70.245 (99.83.70.245) 179.106 ms 178.979 ms 179.737 ms
12 ndn-gw.funet.fi (109.105.102.169) 174.392 ms 179.330 ms 208.335 ms
13 gw.research.netlab.hut.fi (195.148.124.1) 201.649 ms 195.388 ms 195.246 ms
14 * * *
15 * * *
16 * * *
17 * * *
18 * * *
19 * * *
20 * * *
21 * * *
22 * * *
23 * * *
24 * * *
25 * * *
26 * * *
27 * * *
28 * * *
29 * * *
30 * * *
protonot@leader:~/workspace/swis_leader$
```

Follower Truck

```
protonot@protonot:~$ traceroute 195.148.127.155
traceroute to 195.148.127.155 (195.148.127.155), 30 hops max, 60 byte packets
1 _gateway (192.168.222.1) 0.347 ms 0.208 ms 0.222 ms
2 ppp-94-67-142-173.home.otenet.gr (94.67.142.173) 100.107 ms 99.943 ms 99.822
ms
3 ppp-94-67-142-174.home.otenet.gr (94.67.142.174) 109.916 ms 109.796 ms 109.694
ms
4 ppp-94-67-142-193.home.otenet.gr (94.67.142.193) 103.562 ms 103.449 ms 109.370
ms
5 79.128.228.144 (79.128.228.144) 115.385 ms 115.272 ms 115.173 ms
6 62.75.3.69 (62.75.3.69) 115.053 ms 97.183 ms 107.519 ms
7 62.75.14.146 (62.75.14.146) 143.015 ms 62.75.14.150 (62.75.14.150) 147.306 ms
62.75.6.222 (62.75.6.222) 151.222 ms
8 195.66.225.24 (195.66.225.24) 151.092 ms 146.811 ms 146.661 ms
9 de-ffm.nordu.net (109.105.97.79) 162.816 ms 162.696 ms 162.576 ms
10 de-hmb.nordu.net (109.105.97.104) 171.162 ms 171.050 ms 170.942 ms
11 99.83.70.245 (99.83.70.245) 182.012 ms 187.890 ms 183.001 ms
12 ndn-gw.funet.fi (109.105.102.169) 188.603 ms 188.491 ms 182.899 ms
13 gw.research.netlab.hut.fi (195.148.124.1) 176.791 ms 182.543 ms 182.439 ms
14 * * *
15 * * *
16 * * *
17 * * *
18 * * *
19 * * *
20 * * *
21 * * *
22 * * *
23 * * *
24 * * *
25 * * *
26 * * *
27 * * *
28 * * *
29 * * *
30 * * *
protonot@protonot:~$
```

Figure 36: Successful integration of SWIS client devices with IMEC OBUs/Ford trucks

3.2.1.3 *Next steps*

Complete cross- border tests took place at 01 March 2022. Pending tests refer to the applications measurements regarding the Home Routed and LBO scenarios which are expected to have been completed by the mid-April 2022. In these complete tests, the handover event will also be estimated and approached at the application devices level. The verification status of the application is now 100% complete and the relevant measurements are only pending which will be completed during the next cross-border tests (Home Routed and LBO).

3.2.2 US#2.1.b: Platooning through 5G connectivity (5GPlat)

3.2.2.1 *Verification process overview*

Platooning application in vehicles had been tested previously in August 2019 at Ford Otosan Eskişehir Test Premises. This application covers sending commands to vehicle controllers, e.g., braking unit, engine control unit, and steering controller unit, to accomplish required platooning manoeuvres. These manoeuvres are described as *join a platoon*, *dissolve platoon*, *merge-split* and *maintain platoon*. These tests are completed with DSRC communication just for the verification of controllers.

For the 5G-MOBIX project, the same controllers will be used and the same manoeuvres will be accomplished with 5G connectivity. For this purpose, a 5G/LTE site with the NSA architecture has been installed at the Ford Otosan Eskişehir Test Premises. The 5G signal has been also checked with Turkcell and Ericsson TR colleagues. Afterwards, test results for the 5G network have been shared with the consortium.

For 5G Platooning, IMEC OBU, FORD vehicle controller (MABX), and TURKCELL Platooning Cloud connectivity have been designed as depicted in Figure 37.

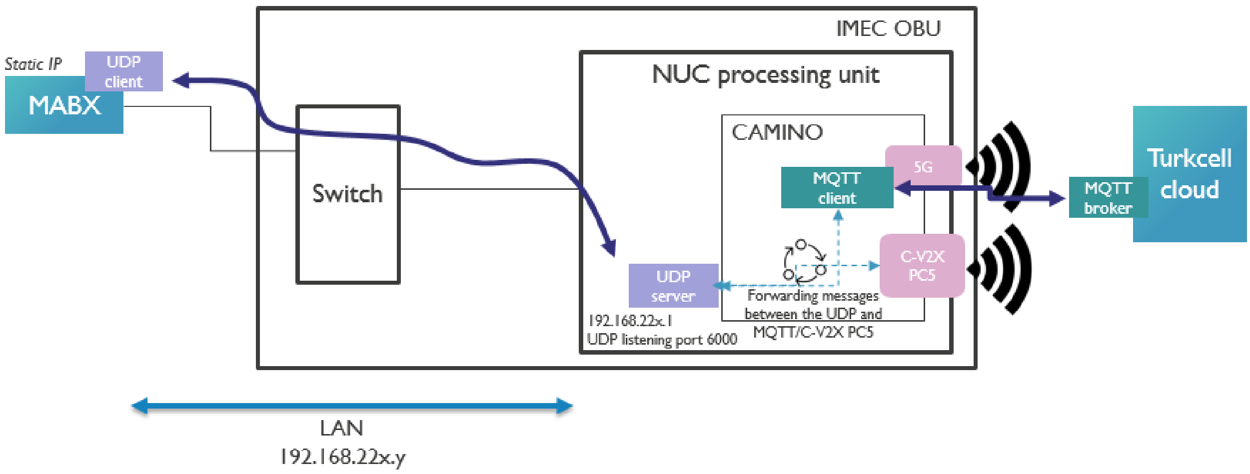

Figure 37: Connection between the different components in the 5G-Platooning use case

3.2.2.2 *Main results*

Table 14 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.2.2):

Table 14: Verification results of the 5GPlat user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	7	0	2	0	89 %
OBU related issues	6	0	0	1	86 %
External servers	2	0	2	1	60 %
Other end user devices	1	0	0	0	100 %
UE related issues	16	0	4	24	82 %
5G network related issues	1	0	0	1	50 %
Network handover related issues	0	0	0	2	0 %
Network related issues	1	0	0	3	25 %
Subtotal: functional issues	12	0	6	8	73 %
Logging related issues	2	0	0	4	33 %
Total	**19**	**0**	**4**	**9**	**66 %**

The integration process in the vehicle is currently still in progress. The OBUs are ready and have been tested, but still have to be integrated in the vehicles. MQTT client has been integrated to IMEC OBUs, with IP addresses and Port numbers have been decided between IMEC and TURKCELL. Message exchange tests between IMEC OBU and Turkcell cloud have been completed on a bench setup.

3.2.2.3 Next Steps

OBUs will be integrated to vehicles, 5G platooning application "object tracking" algorithm will be developed and implemented to vehicle controllers.

After completing the stated steps above, field tests that contain platooning manoeuvres will be tested with 5G connectivity at Ford Otosan Eskişehir test track. Cloud - Vehicle communication and cloud algorithm will be tested until end of March 2022. Test results will be reported.

3.2.3 US#3.2.a: Extended sensors for assisted border-crossing (AssBCrossing)

3.2.3.1 Verification process overview

Early verification of the proper functionality of all the components of the AssBCrossing User Story has been performed by WINGS in their premises in Athens and in Cosmote's facilities, hosting a secondary 5G-testbed (developed as part of the ICT-17 5G-EVE project [10]). These tests have also verified the correct communication and functionality of all the components that will be used in this US, i.e., the OBU, the Roadside Infrastructure (RSI), and the UEs (see 5G-MOBIX Deliverable D3.4 [9]), which were all developed/deployed by WINGS.

Due to the COVID-19 travel restrictions, which are in effect in Greece since October 2020 the integration of the WINGS developed AssBCrossing platform and the OBU, RSI, and UEs with the Ford truck and the 5G network took place in two stages, a) via remote integration sessions between WINGS, IMEC and Ford and b) via physical integration of the WINGS OBU onto the ford truck and the IMEC OBU at the Ford facilities in Eskisehir (Turkey) after the WINGS OBU was shipped to Turkey. For these integration sessions, an identical 5G network deployed at Eskisehir by Turkcell was used. During the early remote integration tests, the proper integration and end-to-end functionality of the WINGS OBU with the IMEC OBU and the Ford truck ECU were tested, via the exchange of messages among the 3 entities and the corresponding actions of the platforms and the truck. For the physical integration part, the WINGS OBU was shipped to Eskisehir, where Ford colleagues received it and installed it in their truck. Another integration session was held with the WINGS OBU now physically installed in the truck and communicating over the Turkcell network, using both Turkcell and Cosmote SIM cards. The final remaining verification step is to test the end-to-end functionality at the actual border and to verify the correct operation during a HO from the Turkcell network to the Cosmote network andd vice-versa. In this way, a big part of the COVID-19 impact has been absorbed and will allow for the successful initiation of the AssBCrossing trials at the borders, according to the updated trial planning (February - May 2022).

3.2.3.2 Main results

Results overview

Multiple integrations and verification tests took place in order to verify the proper functionality of this User Story before deploying it at the GR-TR borders, with all the other components of the GR-TR trials. These tests can be split into three distinct integration/verification sessions:

- Early verification tests using available local 5G network by Cosmote – Cosmote facilities, Athens Greece (October-November 2020)
- Advanced remote verification tests between WINGS, IMEC, and FORD – Remote/Online (September 2021)
- Advanced physical verification tests using the Turkcell 5G network – Ford facilities, Eskisehir Turkey (December 2021)

The detailed checklist of all the verification and integration tests performed for the AssBCrossing US is presented in Annex 2 (Section 6.3.3). The verification process for this US (as with all other USs in the project) has been split into a basic verification process and an advanced verification process. The difference between the two is that the basic version examines that all E2E functionality of the US is available and early trials may begin with the existing working features, while the advanced version examines the functionality of the US while using more advanced or challenging features (e.g., proper roaming relations, mmW, etc.). The existence of the basic versions of USs allows for the beginning of trials, while project partners work in parallel to enable the full functionality of the US, with advanced components. The overview of the status of the basic verification and the advanced verification for the AssBCrossing US, is depicted in Table 15.

Table 15: AssBCrossing Verification checklist – Basic version

	Basic version					Full version				
Group	Pass	Fail	Partly	Not tested	Completion %	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %	9	0	0	0	100 %
OBU related issues	7	0	0	0	100 %	7	0	0	0	100 %
Infrastructure related issues	6	0	0	0	100 %	6	0	0	0	100 %
External servers	5	0	0	0	100 %	5	0	0	0	100 %
Other end user devices	6	0	0	0	100 %	6	0	0	0	100 %
UE related issues	33	0	0	0	100 %	33	0	0	0	100 %
5G network related issues	5	0	0	0	100 %	5	0	1	0	92 %
Network handover related issues	1	0	0	0	100 %	1	0	1	1	50 %
Network related issues	6	0	0	0	100 %	6	0	2	1	78 %
Subtotal: functional issues	39	0	0	0	100 %	39	0	2	1	95 %
Privacy and security issues	1	0	0	0	100 %	1	0	0	0	100 %
Logging related issues	6	0	0	0	100 %	5	0	1	0	92 %
Total	**46**	**0**	**0**	**0**	**100 %**	**45**	**0**	**3**	**1**	**95 %**

It can be seen that the E2E functionality of the AssBCrossing US has been 100% verified using the basic verification criteria, while the advanced verification is also almost complete at 96%. The only thing missing is the verification in the cross-border environment and the verification of the proper HO and roaming process between the Turkcell and Cosmote networks, which will take place February- March. 2022.
The remainder of this section provides some overview information regarding the circumstances of these tests and their outcome.

Integration/verification of AssBCrossing platform with 5G network and Edge servers

The ICT-17 5G-EVE testbed located in Cosmote premises in Athens was used for the early verification of the correct integration of the AssBCrossing platform with the 5G network and the capability to send and receive messages from the OBU, the RSI and the UEs participating in this US. As such it is expected that since the AssBCrossing platform was successfully integrated with the 5G-EVE 5G network, then the platform will also work smoothly with the Ericsson 5G network at the borders.
During the integration tests, which took place on October 30th 2020, a mini-PC hosting the AssBCrossing platform, the WINGS OBU and RSI were transferred to the Cosmote facilities in Athens, and the full end-to-end functionality was tested over the 5G network. The OBU and RSI successfully exchanged messages with the platform over 5G connectivity. In order to test both the cloud-based connectivity and the edge-based connectivity of the platform, both cases were tested. The OBU and RSI were able to communicate both with the AssBCrossing instance residing at the WINGS remote server (cloud-based functionality over the 5G-testbed and the Internet) as well as with the instance residing at Cosmote's Athens facilities edge server (mini-PC – edge-based functionality). Figure 38 depicts a speed test performed over the 5G-testbed, proving the proper integration of the OBU with the 5G-testbed, while Figure 39 depicts part of the server log captured during the integration test, further verifying the proper functionality of the logging mechanisms.

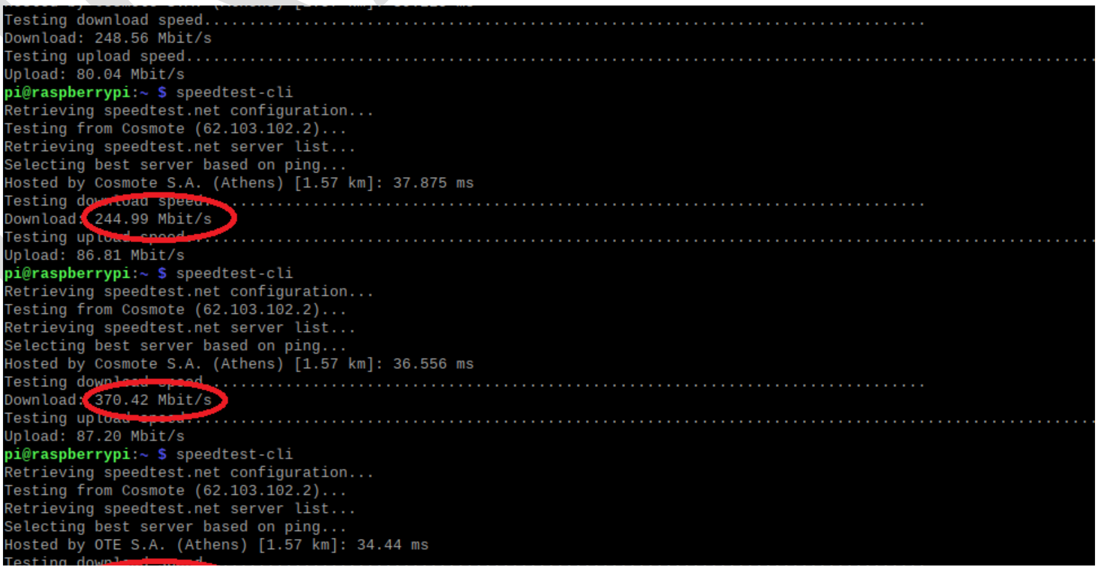

Figure 38: Speed test performed with the WINGS OBU over the Cosmote 5G-testbed in Athens during the AssBCrossing integration test-day

```
{'CO2': 400, 'DISTANSE': 256, 'LAT': 0.0, 'LON': 0.0, 'ECU': [0, 0, 0, 0, 0, 0, 0, 0, 0, 0], 'X': -2.64, 'Y': 5.35, 'Z': -3.98,
'HUMAN': 0, 'IP': '62.103.102.2', 'imei': '863305040124165', 'timestamp': 1604057091.814272, 'TEMPERATURE': 25.0, 'HUMIDITY': 43.67,
'LUX': 11, 'DELAY': 0, 'DROPPEDATA': 0, 'ERROR': 1}
Network Sending time : 0.06123852729797363
{'response': 1}
Packets send : 1 ,lost : 0


{'CO2': 0, 'DISTANSE': 256, 'LAT': 0.0, 'LON': 0.0, 'ECU': [0, 0, 0, 0, 0, 0, 0, 0, 0, 0], 'X': -2.64, 'Y': 5.35, 'Z': -4.02,
'HUMAN': 0, 'IP': '62.103.102.2',  'imei': '863305040124165', 'timestamp': 1604057093.8152018, 'TEMPERATURE': 25.350991442088343, 'HUMIDITY': 43.63,
'LUX': 11, 'DELAY': 0, 'DROPPEDATA': 0, 'ERROR': 1}
Network Sending time : 0.05026125907897949
{'response': 0}
Packets send : 2 ,lost : 0


{'CO2': 400, 'DISTANSE': 256, 'LAT': 0.0, 'LON': 0.0, 'ECU': [0, 0, 0, 0, 0, 0, 0, 0, 0, 0], 'X': -2.64, 'Y': 5.39, 'Z': -3.98,
'HUMAN': 0, 'IP': '62.103.102.2', 'imei': '863305040124165', 'timestamp': 1604057095.815545, 'TEMPERATURE': 25.350991442088343, 'HUMIDITY': 43.62,
'LUX': 11, 'DELAY': 0, 'DROPPEDATA': 0, 'ERROR': 1}
Network Sending time : 0.0407865047454834
{'response': 1}
Packets send : 3 ,lost : 0
```


Figure 39: Server log snapshot during the AssBCrossing integration test-day

The proper functionality of the Double instance (edge functionality) implementation of the WINGS platform was also verified by testing the correct migration of a UE from the WINGS cloud server to the mini-PC that will act as an edge server, utilizing a different IP. The mini-PC was temporarily installed in a secondary network acquiring a different IP/port than the primary cloud instance, hence instantiating the scenario of the double application instance.

The WINGS OBU was used for the test, where the OBU originally attached and transmitted data to the primary (Cloud) instance of the platform, while after passing certain artificial GPS coordinates (set for the purpose of this test), the application level HO process was triggered, the connection between the UE and the server was transferred from the primary (cloud) instance to the secondary (edge) instance and the OBU was instructed to start reporting its measurements to the secondary instance IP/port.

Integration/verification of AssBCrossing platform with Ford Truck (+ IMEC OBU)

The same tests were performed later on in the other two verification sessions, namely the remote sessions between WINGS, IMEC, and FORD that took place in September 2021 and the physical session that took place in December 2021. The message format used for the communication between the FORD truck and the WINGS OBU has been agreed and implemented at both ends. The agreed format is depicted in Annex 1, Figure 99. The proper network-driven triggering of the application level HO process was tested, while the successful status update between two application instances residing at edge data servers, located at edge Data Centers where the overlay vEPC functionalities are deployed, were also verified.

During the remote session, all possible messages between the WINGS OBU and the FORD truck were exchanged and properly received by both ends, thus verifying the proper functionality. During the physical verification tests after the WINGS OBU was shipped to Eskisehir, the entire E2E functionality was put to the test successfully, one more time, while the proper operation of the WINGS OBU under the Turkcell 5G network at Eskisehir was also verified using both SIM cards of Turkcell and Cosmote.

Integration/verification of AssBCrossing platform with OBU, RSI, and UEs

The verification of the proper connection of the WINGS developed OBU, RSI, and UEs with the WINGS platform has been extensively tested at WINGS premises. The OBU successfully connected to the WINGS cloud and edge instance (during different tests) and successfully transmitted and received information to and from the platform. The RSI (camera, smart gate, smart traffic light) successfully connected to the WINGS cloud instance and successfully transmitted video streams and images to be used for license plate recognition, while it also received respective commands (e.g. to close the border gate, to change the traffic light colour, etc.). Finally, a 4G and a 5G UE were used to test the connectivity of UEs with the WINGS platform and the correct functionality of the mobile application Graphic User Interface (GUI) on these smartphones. The mobile version of the GUI was fully functional, and it allowed for the remote control of the OBU (send stop command to the vehicle) and the RSI (remotely close the border gate/traffic light). Figure 40 depicts a snapshot of the AssBCrossing GUI where measurements from the OBU and RSI are reported, proving the correct integration and verifying their functionality.

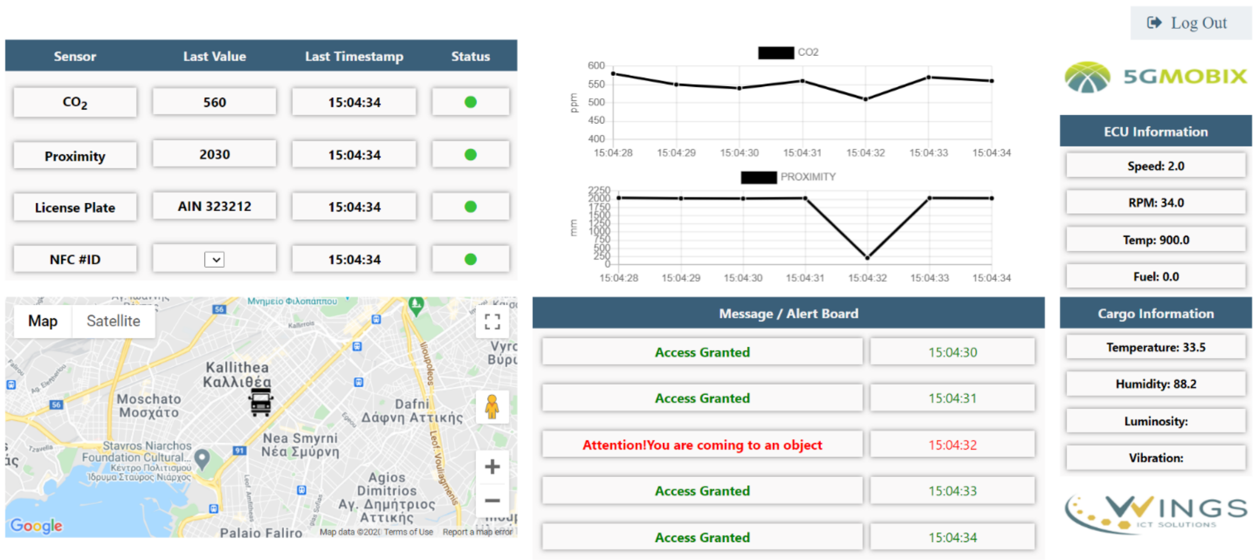

Figure 40: AssBCrossing GUI depicting information/measurements received by the OBU and the RSI

3.2.3.3 Integration/verification Challenges and Next Steps

During the verification and/or integration of the various components and functionalities, some issues were encountered, and alternative implementations had to be found in order to resolve these issues. An overview of these challenges encountered during the development of the WINGS platform and its functionalities, as well as the alternatives that were tested, is presented below.

Live streaming & License plate recognition implementation

<u>1st implementation:</u> TCP Socket to receive streaming images on byte arrays and convert them to jpg files. The following steps are executed:

- The streaming camera sends byte arrays to the socket.

- When the server receives all bytes, a jpg file is being created and sent to license recognition software.
- Each jpg file is served to the live streaming window on the front end.

Challenges/Issues:

- In the case of continuous live streaming a significant packet loss has been detected (~10%).
- Parsing images from the server only when socket re-opens for every file. Opening TCP socket introduces unwanted delay on stream.

2nd implementation: TCP Socket to receive an image on a base64 format (delay). The following steps are executed:

- The streaming camera converts each frame to a base64 string and sends it to the server.
- When the server receives each packet (abase64 string), converts it to a jpg file and sends it to license recognition software.
- Each jpg file is served to the live streaming window on the front end.

Challenges/Issues:

- The conversion of the image is a time-consuming process.
- Parsing images from the server only when socket re-opens for every file. Opening TCP socket introduces unwanted delay on stream.

3rd implementation: RTMP video streaming. The following steps are executed:

- FFmpeg stream from RSU to server (RTMP encoding).
- Nginx module allows recording video to file, while able to forward video as HLS to the frontend

Challenges/Issues:

- Stream recording output has approximately 7 seconds delay from real time.

4th implementation: UDP Socket to receive streaming images (high resolution) on byte arrays. The following steps are executed:

- The streaming camera divides every jpg file into multiple frames (65000 > framebytes) and sends every frame along with the number of the jpg file.
- When the expected number of packets are received, the server creates a jpg file from the received packets and sends it to license recognition software.
- Each jpg file is served to the live streaming window on the front end.

Challenges/Issues:

- Due to the UDP connection, packets are reaching the server asynchronously. When receiving a huge number of packets, images are mixed up and are not saved properly.

5th implementation: UDP Socket to receive streaming images (lower resolution) on byte arrays. The following steps are executed:

- The streaming camera sends one UDP packet for every image file (65000 > jpgsize).
- Server creates a jpg file from the received packet and sends it to license recognition software.
- Each jpg file is served to the live streaming window on the front end.

Currently, this is the approach that is being followed by the WINGS platform, and no issues have been detected so far. The WINGS team is currently working on improving the quality of the image resolution, which is currently limited by the UDP file size.

Acquisition of smartphone GPS coordinates

1st implementation: ShareGPS Android app. The following steps are executed:

- Setup for TCP/UDP socket data transmit from phone to server.

  Challenges/Issues:
- Not able to receive data specifically from Samsung s10/s20 5G company's smartphones for an unknown reason.
- Firewall at Cosmote edge facilities does not allow the commercial application to reach the Google API to retrieve the Google maps data. Only IP white-listing can be offered by Cosmote, but the Google maps API uses a multitude of unknown IPs (depending on location).

2nd implementation: Custom Android app for retrieving the GPS coordinates

A custom Android application has been developed by WINGS, which will be installed in the respective 5G smartphones to be used by the customs agents and will transmit their GPS coordinates (lat, long) to the WINGS platform in real time. As the WINGS platform will be housed in three different locations (WINGS office @Athens, Alexandroupoli Edge, and Istanbul Edge), three different versions of the application will be created, forwarding the GPS coordinates to the respective location.

This implementation also resolves the issue with the Cosmote firewall, as the custom WINGS application uses a single known IP to transmit the GPS coordinates, which can be white-listed, allowing for the proper functionality of the platform.

3.2.4 US#3.2.b: Truck routing in customs area (TruckRouting)

3.2.4.1 Verification process overview

The verification of the proper functionality of all the components of the TruckRouting User Story has been performed remotely due to COVID-19 restrictions. The connection between RSUs and TUBITAK Cloud has been tested by IMEC and TUBITAK before the shipment of RSUs to Turkey. RSUs have connected successfully to the TUBITAK Cloud without 5G. They are currently at Turkcell facilities and being tested for 5G connectivity. Integration of Truck Routing Application and FORD truck has also been tested remotely. Safe waypoints have been produced by Truck Routing Application for some scenarios using mock-up data and sent to FORD. FORD has tested these waypoints on the truck at FORD facilities in Eskişehir. The truck has followed the waypoints successfully but the need for fine tuning of safe waypoints has been noted to ensure a more stable route between the beginning and end locations. Testing of some of the Truck Routing Application functionalities is still ongoing.

3.2.4.2 Main results

The detailed checklist of all the verification and integration tests performed for the TruckRouting User Story is presented in Annex 2 (Section 6.3.4). The remainder of this section provides some overview information regarding the circumstances of these tests and their outcome.

Table 16: Verification results of the TruckRouting user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	7	0	0	0	100 %
Infrastructure related issues	4	0	0	0	100 %
External servers	5	0	0	0	100 %
Other end user devices	1	0	0	0	100 %
UE related issues	26	0	0	0	100 %
5G network related issues	2	0	0	0	100 %
Network related issues	2	0	0	0	100 %
Subtotal: functional issues	28	0	0	2	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	0	0	3	3	25 %
Total	**29**	**0**	**3**	**3**	**87 %**

Integration/verification of Truck Routing Application with Ford Truck

Figure 41 and Figure 42 depict the analysis of the FORD truck's trajectory. Truck Routing Application has produced safe waypoints for some scenarios using mock-up data. The safe waypoints have been tested on the FORD truck offline. It was observed that waypoints caused some slaloms at high speeds. Fine tunings are still ongoing for solving this issue.

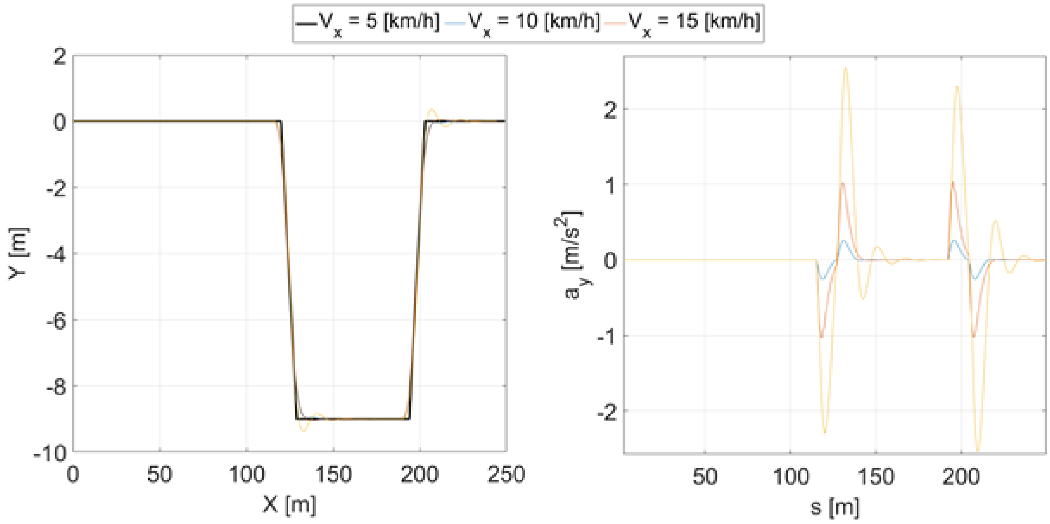

Figure 41: Path following performance for vehicle speed

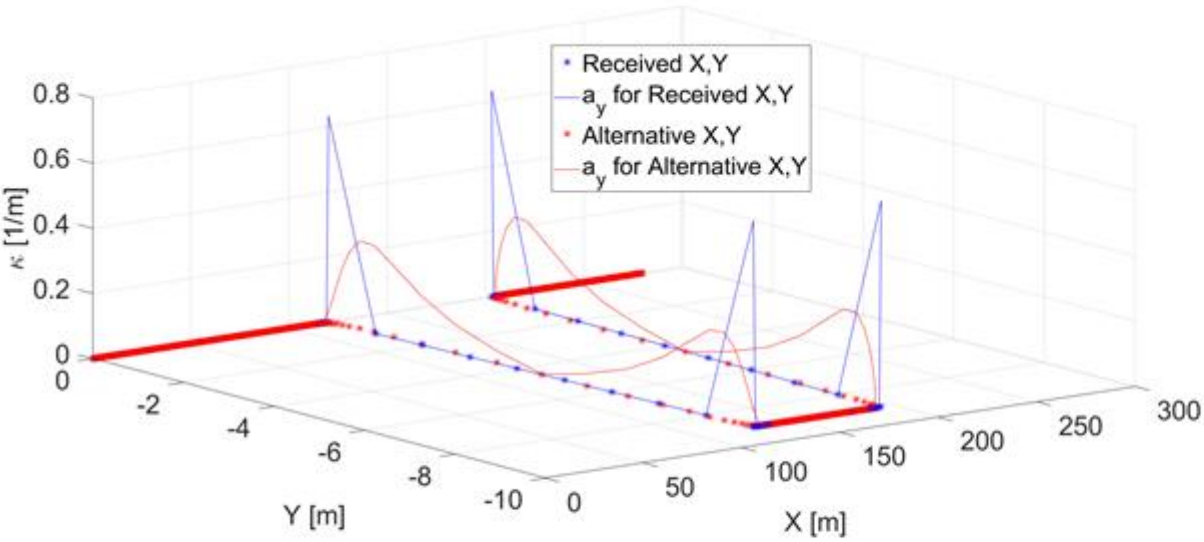

Figure 42: Curvature analysis of received trajectories

3.3 Local Test Site Germany

3.3.1 US #2.2 eRSU assisted platooning (AsseRSU)

3.3.1.1 Verification process overview

In the eRSU-assisted platooning user story there are two vehicles involved, one in the front that has the role of the platoon leader, and one behind it that has the role of a follower. They exchange different types of platooning custom messages in order to establish the platoon (handshake) and to exchange information to give the correct commands to the driver of the follower vehicle (there is no automation of the vehicle's actions at DE TS; the platoon is emulated), in order to follow the platoon leader. The platoon leader is also processing Cooperative Perception Messages (CPMs) and other infrastructure ITS messages received from two different eRSUs, located in two different MNO domains, with the aim of having an enhanced perception of the road.

The communications infrastructure and the messages exchange involved in this US are depicted in Figure 43. The verification tests have been performed for all the components and applications present in the platooning US along with the DE-TS location:

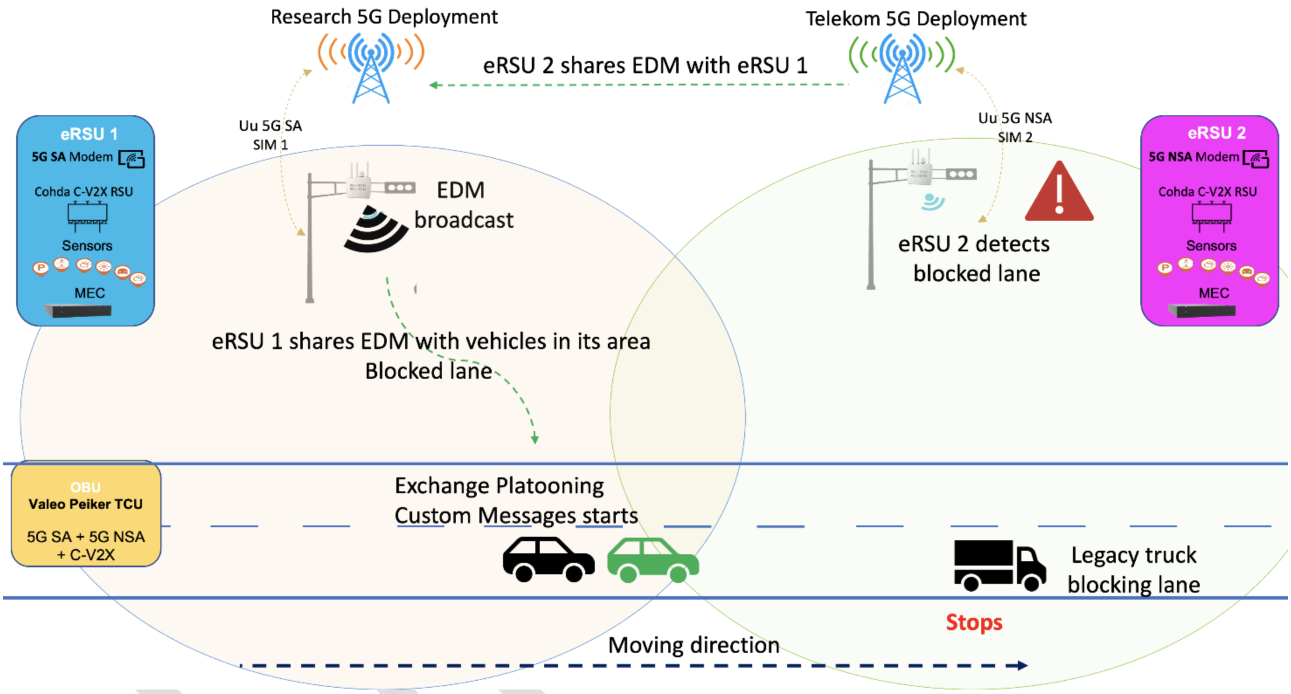

Figure 43: Platooning main components and messages

3.3.1.2 *Main results*

Table 17 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.2.3):

Table 17: Verification results of the AsseRSU user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	8	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
Infrastructure related issues	4	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	26	0	0	0	100 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	1	0	0	0	100 %
Network related issues	9	0	0	0	100 %
Subtotal: functional issues	35	0	0	0	100 %
Privacy and security issues	2	0	0	0	100 %
Logging related issues	6	0	0	0	100 %
Total	**43**	**0**	**0**	**0**	**100 %**

All tests have been successfully passed, providing good final results after the verification trials. The platooning application has been tested and all messages have been correctly received by the platooning vehicles, proving the correct performance of the application workflow and behaviour. This application was completed by May 2021. The communication between eRSUs, OBUs, and MEC has also been verified by sending and receiving infrastructure messages via the 5G-NSA Uu interface. The servers installed in the MEC forward the ITS messages in the established format to the vehicles along the test area, depending on their current location and heading.

The two photos below show the setup installed in TUB and Valeo vehicles, which were used for the verification tests in the early trials at the end of March 2021. In both vehicles, all physical components needed (OBUs, 5G modems, and cameras) are available and operate as expected.

Figure 44: Vehicles from TUB and Valeo used for the verification tests

Regarding the 5G coverage in the DE-TS, 5G-NSA network availability has been verified along the complete route used in both USs. The purple points shown in the two figures below indicate that the Radio Access Technology (RAT) used is 5G-NSA. The first figure is for the O2 network and the second figure is for the DT network, which are the two MNOs currently used in the trials.

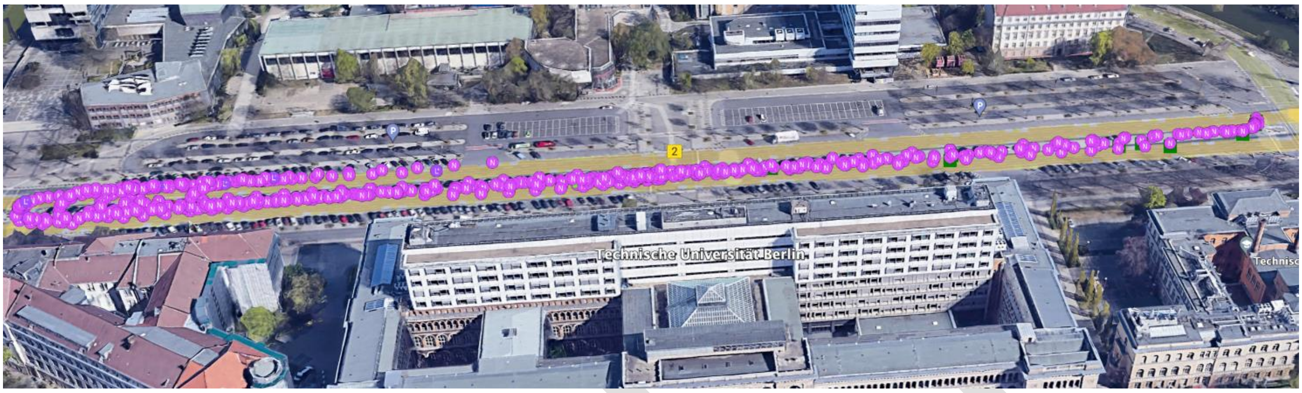

Figure 45: 5G-NSA coverage for O2 in the DE-TS

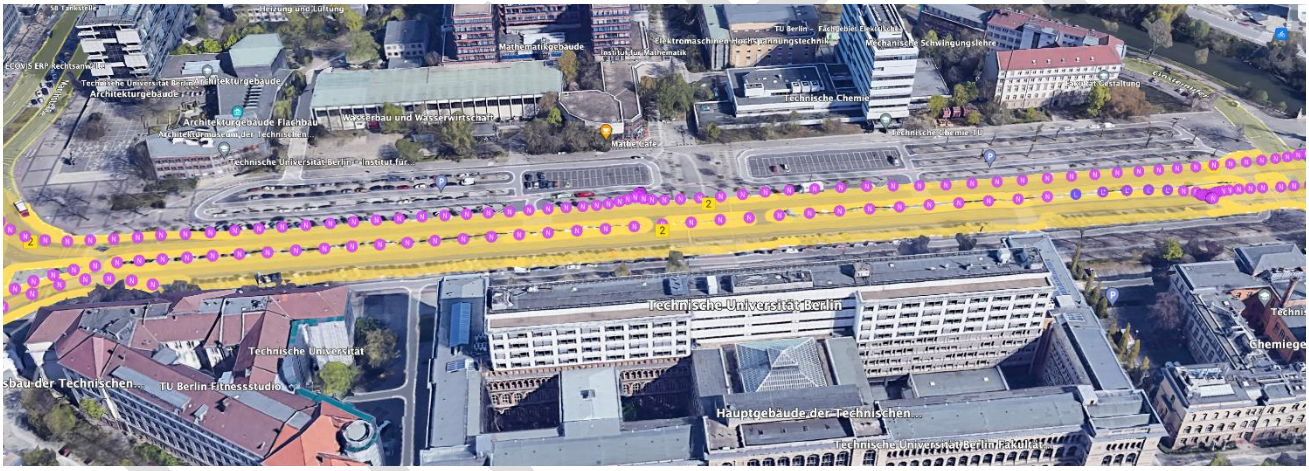

Figure 46: 5G-NSA coverage for the DT in the DE-TS

For the 5G NSA network from Deutsche Telekom, some quick performance tests have been realized. The results were all similar to the ones presented in the screenshot below:

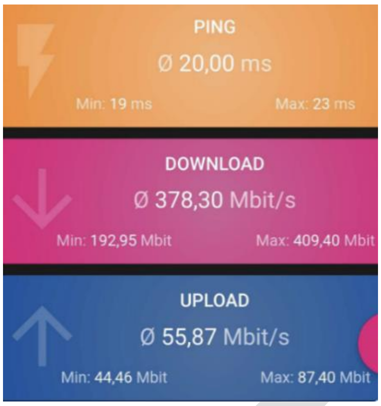

Figure 47: Performance test with 5G NSA network from Deutsche Telekom

In order to verify the correct communication through the PC5 interface, the transmission and reception of CAM messages from the different components have been monitored between an OBU and the two eRSUs available. In the screenshot below the messages received by one of the units are captured.

```
Packet received Transport:TSB NH:BTPB PL:126 (GN_ADDR 0x140004E548230106, TST:2595474604)
CAM received, stationID 0x48230106 (1210253574)
CAM generated, stationID 0x00000dad (3501)
Packet received Transport:TSB NH:BTPB PL:126 (GN_ADDR 0x140004E548230106, TST:2595475604)
CAM received, stationID 0x48230106 (1210253574)
CAM generated, stationID 0x00000dad (3501)
Packet received Transport:TSB NH:BTPB PL:126 (GN_ADDR 0x140004E548230106, TST:2595476604)
CAM received, stationID 0x48230106 (1210253574)
CAM generated, stationID 0x00000dad (3501)
Packet received Transport:TSB NH:BTPB PL:126 (GN_ADDR 0x140004E548230106, TST:2595477604)
CAM received, stationID 0x48230106 (1210253574)
CAM generated, stationID 0x00000dad (3501)
```

Figure 48: Transmission of ITS messages between OBUs

For the synchronization of the different components involved in the platooning US, the solution adopted is to synchronize each of the units with their local received GPS signal, as it is available for the majority of them. The GPS clock signal received in the C-V2X units, available in all vehicles and eRSUs, is broadcasted to their Local Area Network (LAN) using a PTP (Precision Time Protocol) server. The computers where the applications run have a PTP client that synchronizes their system clock with the GPS clock with very high precision. For the synchronization of the MECs, in the case of the TUB MEC, the same approach is used as one of the eRSUs can broadcast the PTP signal to it. For the case of the MobiledgeX MEC, located in the Deutsche Telekom network, they are currently working on a solution to synchronize all running components with a GPS clock. By the time of writing this deliverable in March 2022 Deutsche Telekom is working on upgrading its currently ntp-synced datacenter to GPS-sync, so that all components in this user story are fully synchronized

3.3.1.3 *Next steps*

After the early trials have been accomplished, where vehicles are receiving messages from each other or from an eRSU, complex scenarios will follow, including the emulated roaming processes where eRSUs located in different domains exchange EDM data. In the early trials, the tests are performed using the commercial NSA network from Deutsche Telekom and a single eRSU attached to this network.

3.3.2 US#3.3: EDM-enabled extended sensors with surround view generation (EDM)

3.3.2.1 *Verification process overview*

The tests to verify the setup will be performed on top of the logical infrastructure depicted in Figure 49, more information on the components of the distributed surround view application can be found in D3.4

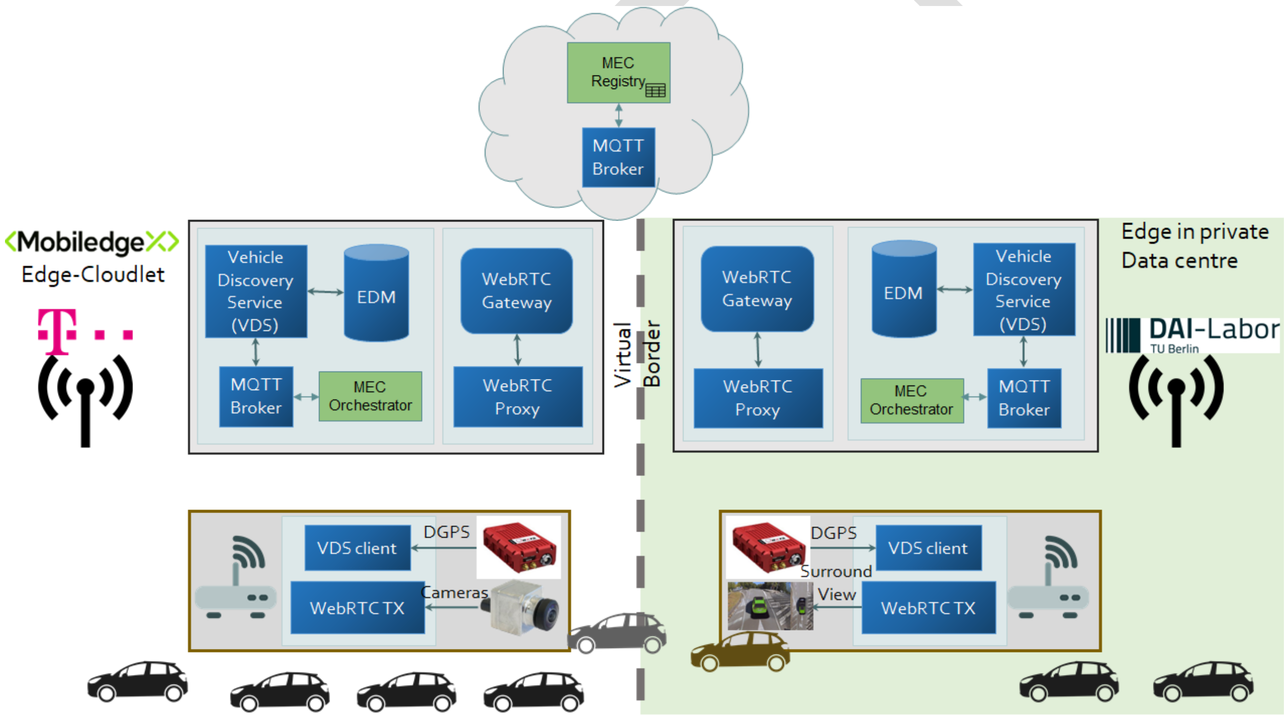

Figure 49: Logical infrastructure for the EDM user story

From a communications infrastructure perspective the building blocks will involve the networks, technologies, and resources depicted in Figure 50.

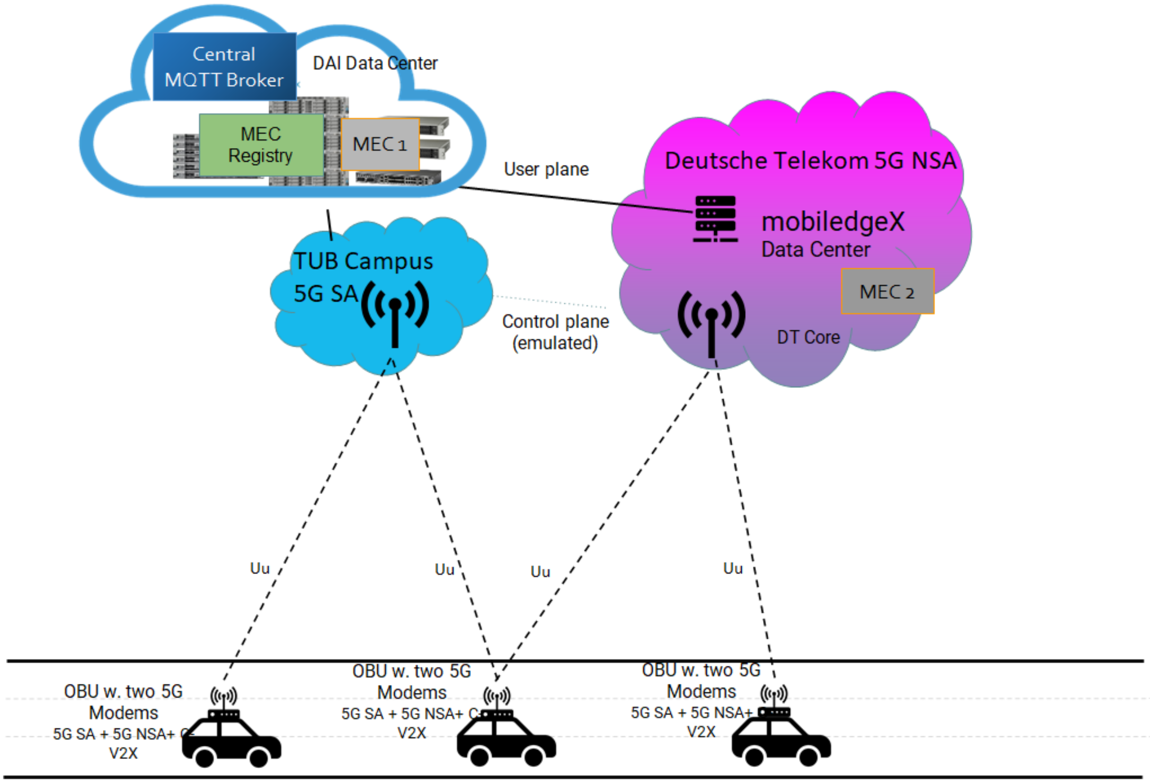

Figure 50: Communication architecture building blocks for the EDM user story

3.3.2.2 *Main results*

Table 18 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.3.5):

Table 18: Verification results of the EDM user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	8	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	22	0	0	0	100 %
5G network related issues	7	0	0	0	100 %
Network handover related issues	0	0	0	0	0 %
Network related issues	7	0	0	0	100 %
Subtotal: functional issues	29	0	0	0	100 %
Privacy and security issues	4	0	0	0	100 %
Logging related issues	6	0	0	0	100 %
Total	**39**	**0**	**0**	**0**	**100 %**

Different verification tests have been done in order to be sure that all the components, SW, HW, and connectivity were in place and working properly.

Once all the corners were checked, some static tests with native and partial applications stressing just the communications perspective, not the CCAM application itself, were performed in order to get some results when movement or dynamic performance comes into play.

These tests included the execution and logs capturing for different throughput demands in order to get some performance logs from a baseline execution to a more demanding one. Step by step, the bitrate, resolution, and framerate were increased in order to be sure that no side bottlenecks, apart from connectivity from the UE or the Edge, are impacting the CCAM application.

Once the static tests were done, the CCAM application tests were performed using the most demanding configuration.

Table 19: Results of CCAM application tests

Setup	Bitrate	Round-trip-time (avg)	Jitter (min-max)	Startup time (avg)
Low Coverage NSA	1 Mbps	105 ms	0.3-5.2 ms	10.2 secs
High Coverage NSA	10 Mbps	4.9 ms	0.2-1.2 ms	8.7 secs

Concerning the synchronisation results, the MEC was running a NTP service, and vehicles executed some messaging clients in order to get accuracy. The mean clock difference for transmission was 0.0353 seconds and for reception 0.0405 seconds.

Some conclusions from the tests done are:

- Some connectivity bottlenecks come from the MobilEdgeX, which are minimized when the computing capacity is increased, moving from a 2cores/2GBRAM machine to 4cores/8GBRAM
- Coverage of SA is poor in the parking area and it needs some debugging and updates on Vulcano TCU
- NSA smartphones as UEs get higher bandwidth than Quectel UEs NSA

3.3.2.3 Next steps

In a second iteration, once individual SA and NSA networks and infrastructures are tested, verification will move to roaming situations with a virtual border splitting the road in two logical and physical network areas. Here, the MEC registry gets relevance, easing the multiple utilization and migration of MEC services, not as individuals but as actors participating in the user story in different stages.

3.3.3 Contribution to ES-PT CBC: Extended sensors solution including 5G connected car, Multi SIM OBU, PC5 RSUs, and MEC instances

3.3.3.1 Verification process overview

The DE TS has already verified most of the components. The remaining points are related to the networks deployed in the ES-PT CBC. At the end of February 2022 there are still network problems in the ES-PT CBC that prevented to complete the verification of handover and roaming related aspects.

Table 20: Verification results of the contribution of the German trial site to the ES-PT CBC

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	7	0	0	0	100%
OBU related issues	9	0	0	0	100%
UE related issues	16	0	0	0	100 %
5G network related issues	8	0	0	0	100%
Network handover related issues	1	0	0	2	33%
Network related issues	9	0	0	2	82%
Subtotal: functional issues	25	0	2	2	93%
Privacy and security issues	2	0	0	0	100%
Logging related issues	6	0	0	0	100%
Total	**34**	**0**	**2**	**2**	**94%**

3.3.3.2 Next steps

The DE TS team is planning a trip to the ES-PT CBC in the first week of March to collect data for the evaluation. Depending on the results obtained, as well as the status of handover of roaming works in the ES-PT CBC, further trips will be planned.

3.4 Local Test Site Finland

3.4.1 US#3.4: Extended sensors with redundant edge processing (EdgeProcessing)

3.4.1.1 Verification process overview

The FI TS extended sensors user story constitutes two developments from AALTO, namely, a crowdsourced HD mapping application and a service discovery system that enables a UE (vehicle) to discover a MEC in a visited network as illustrated in Figure 51. The HD map applications running on the MEC create and/or update the 3D map in a timely manner, whenever the environment changes based on the crowdsourced video streams received from the vehicle. The realisation of the user story required integration and testing of the service discovery and HD maps solution running on the edge, with initial testing done in the lab environment, before deploying client devices in the vehicle and doing verification tests on the test roads with coverage by multiple PLMNs.

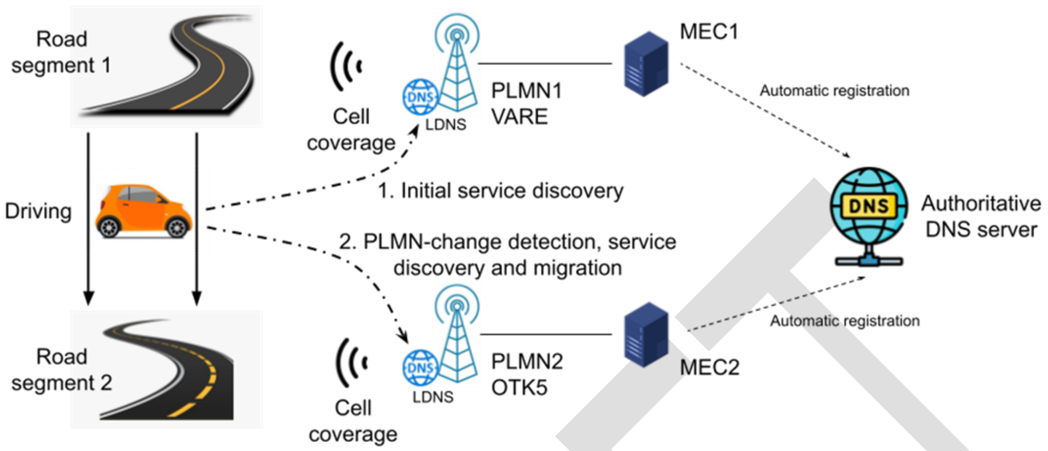

Figure 51: Edge service discovery and migration for the FI-TS extended sensors user story

The verification process for the FI-TS extended sensors user story has been conducted iteratively beginning from the initial development, integration, and testing of the constituent applications (service discovery and HD maps) in the lab environment in the period leading up to December 2020 (M26).

The extended sensor pre-trials took place in February 2021 (M27) at the FI-TS in the Otaniemi campus of Aalto University. The purpose was to verify basic connection and traffic flows between the different components (in-vehicle devices, network, edge platforms) and the applications used in the user story. During the pre-trials, the edge service (dynamic or automatic) registration and discovery applications were tested, and video data from three dashboard cameras was transmitted via the 5G networks to the cloud and edge, and video was visualized in real-time in a laptop computer. Figure 52 shows a screenshot of the edge computing platform interface with HD maps.

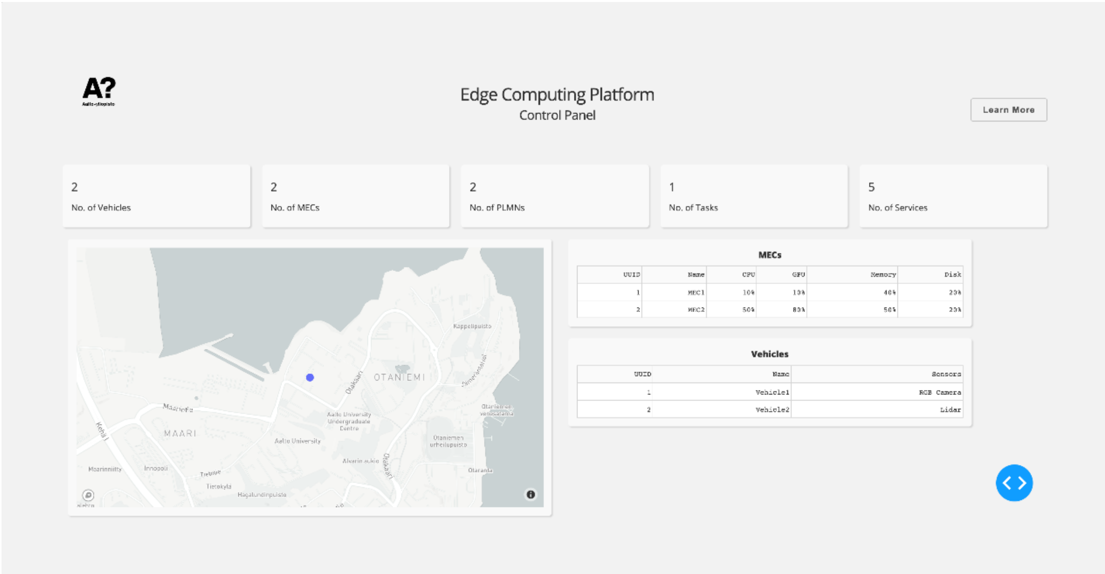

Figure 52: Screenshot of the edge computing platform interface with HD maps

Subsequent trials extended sensors tests and trials were conducted in M32 that verified use story steps when particularly in relation to the edge service discovery and migration with the handovers done by the multi-SIM OBU actively selected connections between two 5G NSA networks. Moreover, these trials were used to test and verify the logging and measurement framework for the user story to obtain KPIs for use in evaluation activities of WP5.

3.4.1.2 Main results

The high-level view of the overall verification test steps considered in the remote driving testing and early trials is shown in Table 21 below. The completeness and maturity of the implementation of each verification test step have been increasing iteratively for each trial leading up to the final demo and trial.

Table 21: High level verification test steps for FI-TS extended sensors (EdgeProcessing) user story

	Verification Test Steps	Verification Means / Checklist Item Involved
1	Vehicle sends registration messages to the edge controller and sends DNS query to the LDNS-1 (LDNS for PLMN-1), receiving the IP address of MEC-1 (MEC of PLMN-1) as DNS response.	Verification by registration and service discovery results, along with latency.
2	Vehicle sends video streams to MEC-1 and receives updated HD maps.	Verification using video streaming performance and success of object detection.

	Verification Test Steps	Verification Means / Checklist Item Involved
3	Vehicle connection to edge controller is changed between PLMN-1 and PLMN-2 using multi-SIM OBU network handover	Logging of performance during network handover
4	Vehicle sends DNS query to the LDNS-2 and receives the IP address of MEC-2 as DNS response.	Verification using service discovery results and latency.
5	Vehicle sends video streams to MEC-2 and receives updated HD maps.	Verification using video streaming statistics and object detection statistics.

Table 22 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.3.6). At the end of February 2022, the unverified items in Table 22 are mostly attributed to the delay in implementing the user story in outdoor networks with SA-SA roaming. This has not been an impediment in conducting extended sensors trials with two NSA networks and multi-SIM OBUs used to do network handover that triggers the MEC service discovery and migration. It is noted that implementation, testing, and verification of the FI-TS SA-SA roaming implementation has been ongoing using indoor test network setup.

Table 22: Verification results of the EdgeProcessing user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	6	0	0	0	100 %
OBU related issues	5	0	0	0	100 %
Infrastructure related issues	1	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	17	0	0	0	100 %
5G network related issues	4	0	0	0	100 %
Network handover related issues	2	0	1	0	83 %
Network related issues	6	0	1	0	93 %
Subtotal: functional issues	23	0	1	0	98 %
Privacy and security issues	2	0	0	0	100 %
Logging related issues	3	0	3	0	75 %
Total	**28**	**0**	**4**	**0**	**94 %**

3.4.1.3 *Next steps*

At the current time of reporting, there is ongoing preparation for final FI-TS extended sensors trials and demos, tentatively scheduled for M42. The previous remote driving trials have been conducted in an environment with two 5G networks in NSA mode. The upgrade of the OBU to support SA mode and SA upgrades AALTO's 5G research network, provides an opportunity to rerun the extended sensors trials under SA network coverage with SA-SA roaming.

3.4.2 US#4.2: Remote driving in a redundant network environment (RedundantNE)

3.4.2.1 Verification process overview

The FI TS remote driving user story constitutes two main applications. These are the primary remote driving application that runs between the vehicle and the Remote Operations Centre (ROC) and the LEVIS video streaming application. In the user story vehicle connects to a fleet control server through a 5G network connection share data, such as position, obstacles, operations, video feeds, etc., that is used by the remote human operator to confirm new route proposals in case of anomalies arise that the vehicle cannot handle itself. The overall user story required parallel development of the remote driving application pipeline (by SENSIBLE4) and the LEVIS video stream platform (by AALTO) and their eventual integration, testing, and verification on the FI TS test route under 5G network coverage.

As was the case with the FI-TS extended sensors user story in Section 3.4.1, the verification activities for the FI-TS remote driving user story have occurred iteratively from the development and deployment phase of the constituent CCAM applications, as well as 5G network assets and OBUs targeted for use in the FI TS trials. This included the initial integration testing of the remote driving and LEVIS video streaming applications in lab or test facilities within the final quarter of 2020.

Thereafter, the FI TS Remote Driving pre-trials took place M27 at the Otaniemi campus of Aalto University. The purpose was to verify basic connections and interactions between the different components and systems. This included the transfer of data between the L4 vehicle and the ROC with a remote human operator for the vehicle. The same preparations and test setup for the extended sensors pre-trials (except for the usage of the MECs), described in the previous section, also hold for the remote driving pre-trials. Additionally, the test route was scanned before each trial (see Figure 53) to create 3D maps used for navigation by the autonomous vehicle during the trials.

Figure 53: The automated test vehicles scanning the test route

The test vehicle, operated by Sensible4, drove in automated mode in open roads of the designated FI-TS test route and with mixed traffic, e.g., public buses, service trucks, and pedestrians, and under challenging winter condition (-18 degrees Celsius reported on both days; see Figure 54).

Figure 54: The remote driving pre-trials of the Finland trial site

The subsequent trials and test sessions provided an opportunity for further verification of features and actions within the remote driving user story. This has included the early trials in M29 which provided the first complete implementation of the applications included in the remote driver user story and testing of updated network (re)selection criteria to reduce 'ping-pong' effects when the multi-SIM OBU was selected between two 5G NSA networks. The next trials in M34 provided experimental verification of the multi-SIM performance enhancements when compared to the single-SIM case in the context of the remote driving user story.

3.4.2.2 Main results

The high-level view of the overall verification test steps considered in the remote driving testing and early trials is shown in Table 23 below. The completeness and maturity of the implementation of each verification test step have been increasing iteratively for each trial leading up to the final demo and trial.

Table 23: High level verification test steps for the FI remote driving user story

	Verification Test Steps	Verification Means / Checklist Item Involved
1	Vehicle sends status messages and LiDAR stream to ROC at the beginning of the FI-TS route.	Vehicle sensors, automated driving (AD) system, 5G multi-SIM OBU, 5G network.
2	Vehicle faces obstacle and requests assistance from ROC and starts to also send video (live stream and pre-recorded) to ROC	Vehicle sensors, automated driving (AD) system, video streaming clients and servers, 5G multi-SIM OBU, 5G network.
3	Remote human operator at ROC accepts the new trajectory and vehicle executes manoeuvre around obstacle continues driving on the route	Remote operator interaction with vehicle via the ROC user interfaces.

	Verification Test Steps	Verification Means / Checklist Item Involved
4	Vehicle connection to ROC is changed between PLMN-1 and PLMN-2 using network handover (with multi-SIM OBU) or SA-SA roaming	Two 5G networks (NSA and/or SA mode) with separate RAN and core infrastructure and distinct PLMN-IDs, but overlapping coverage footprint.
5	Vehicle continues sending status message, LiDAR and video stream to ROC and terminates the traffic streams at the end of the route	Vehicle sensors, automated driving (AD) system, 5G multi-SIM OBU, 5G network.

Table 24 gives an overview of the statistics of the checklist issues tested for the FI-TS remote driving user story in the pre-trials and follow-up trials and test campaigns, details of which can be found in Annex 2 (Section 6.4.2). At the end of February 2022, the unverified items in Table 24 are mostly attributed to the delay in implementing the user story in outdoor networks with SA-SA roaming. This has not been an impediment in conducting remote driving trials with NSA networks and multi-SIM OBUs.

Table 24: Verification results for the FI remote driving user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	4	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	18	0	0	0	100 %
5G network related issues	1	0	1	0	75 %
Network handover related issues	1	0	1	0	75 %
Network related issues	2	0	2	0	75 %
Subtotal: functional issues	20	0	2	0	95 %
Privacy and security issues	2	0	0	0	100 %
Logging related issues	5	0	1	0	92 %
Total	**27**	**0**	**3**	**0**	**95 %**

3.4.2.3 Next steps

At the current time of reporting, there is ongoing preparation for final FI-TS remote driving trials and demos, tentatively scheduled for M42. A significant part of the preparation is the verification of the new 5G network and OBU features or configurations that will be tested in the remote driving user story. Furthermore, the previous remote driving trials have been conducted in an environment with two 5G networks in NSA mode. The upgrade of the OBU to support SA mode and SA upgrades AALTO's 5G research network, provides an opportunity to rerun the remote driving trials under SA network coverage. The OBU SA upgrade has been verified, whereas verification of the SA network coverage and SA-SA roaming is ongoing for outdoor networks.

3.4.3 Contribution to GR-TR CBC: LEVIS video streaming application

3.4.3.1 Verification process overview

The LEVIS video streaming application has been initially checked and verified in the framework of Remote Driving use case as it is described in Section 3.4.2. In that user story the video encoding process, the dual connectivity streaming with DASH technology using H.264.encoder, and the emerging latency have been adequately addressed. In the framework of the See-What-I-See application in GR-TR CBC LEVIS server and client contribute to the necessary service continuity with two clients being placed in both the leader and follower trucks while the server facilitates the video streaming process from the leader to the follower (see Figure 55). The FI tests which initially addressed the latency aspects, were then further checked and tested with two clients - in correspondence with the leader status and the follower status trucks of GR-TR CBC.

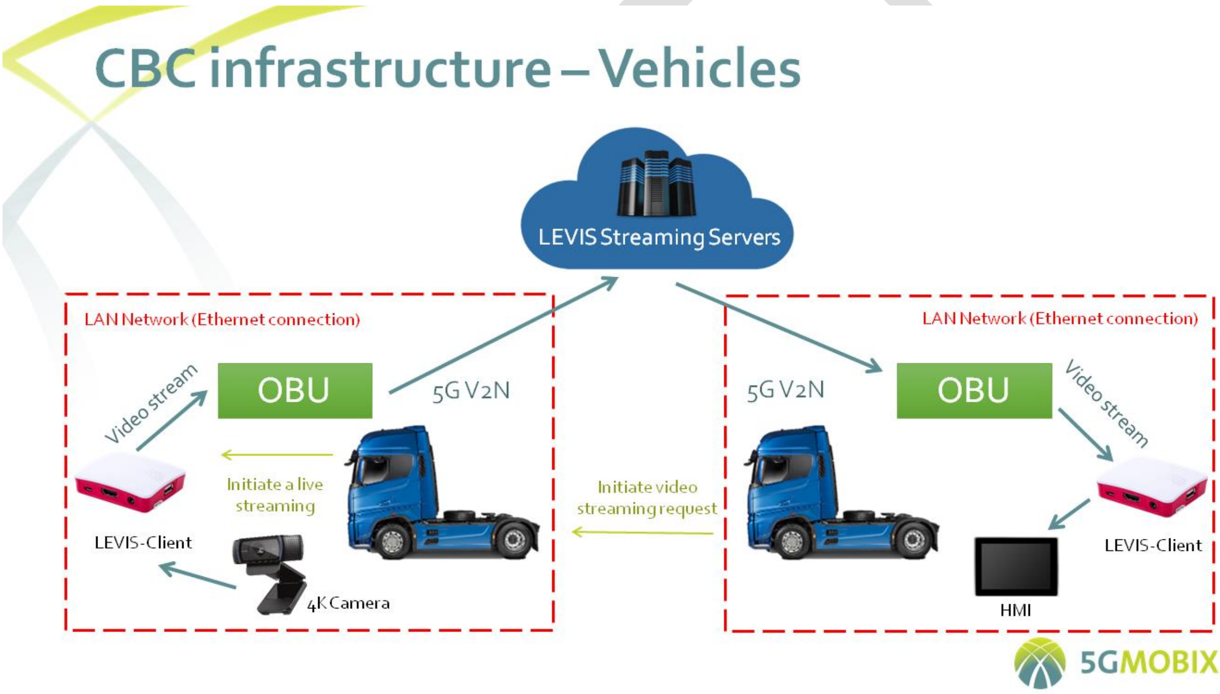

Figure 55: LEVIS video streaming in the GR-TR CBC

The subsequent joint testing and verification of the LEVIS contribution to the GR-TR SeeWhatISee user story is described in more detail in Section 3.2.1. The travel constraints attributed to the Covid-19 restrictions meant that AALTO had remotely collaborated with ICCS and others GR-TR partners in the installation of the LEVIS application, as well as, testing and verification of the SeeWhatISee user story.

3.4.3.2 Main results

The use case is an integral part of the GR-TR SeeWhatISee user story, which is described in Section 3.2.1.

3.4.3.3 *Next steps*

As noted previously in Section 3.2.1, the LEVIS contribution will be incorporated in the SeeWhatISee user story trials at the GR-TR cross- border expected to take place in March 2022. The goal of these tests is to verify the full functionality of the application's objectives during Home Routing and Local Breakout video streaming tests when the trucks cross the GR-TR borders. The Handover event will also be estimated and approached at the application level in the upcoming tests. After the above points have been tested and confirmed, the verification status will be at 100% total completion and ready for the final trials.

3.4.4 Contribution to ES-PT CBC: Edge discovery service

3.4.4.1 *Verification process overview*

The verification of the baseline functionality of the edge discovery service solution was conducted initially within the context of the FI-TS *US#3.4 Extended Sensors with Redundant Edge Processing* (EdgeProcessing) as described previously in Section 3.4.1. Subsequently, the edge discovery solution has been updated and redeployed in the ES-PT as part of *US#3.1.a: Complex Manoeuvres in Cross-Border Settings: HD Maps* (HDMapsVehicle) and *US#3.1.b: Public Transport: HD Maps* (HDMapsPublicTransport).

Different roaming configuration configurations are implemented by MNOs in ES-PT CBC, namely, Home Routing and Local Breakout, which impact differently the edge discovery solution. At the end of February 2022, the Home Routed configuration was implemented in the CBC. However, service discovery cannot be triggered in this configuration during handover from one network to another. On the other hand, the Local Breakout configuration allows for testing of the service discovery and migration when the HO occurs with the corresponding IP change. At the time reporting, the ES-PT CBC Local Breakout implementation was expected by May 2022.

3.4.4.2 *Main results*

The contribution is an integral part of the HDMapsVehicle and HDMapsPublicTransport user stories. The evaluation of these user stories is reported in Sections 3.1.4 and 3.1.5, respectively.

3.4.4.3 *Next steps*

The next step is the upcoming trials of the ES-PT CBC user stories including this edge discovery service contribution. These trials will be conducted in the International Bridge (A55) from February to May 2022 (M40-M42). At the end of February 2022, there are no plans for demos in the real road (with road-closures) with HDMaps, but it will be feasible to carry out trials in CTAG tracks if required. Further details of the trial plans are outlined in Sections 3.1.4 and 3.1.5.

3.4.5 Contribution to ES-PT CBC: Multi-SIM OBU solution

3.4.5.1 Verification process overview

The multi-SIM OBUs in FI-TS have gone through a series of iterative configuration and testing operations to ensure their reliable operation in the series of local trials in FI-TS and later testing activities planned for the ES-PT CBC. This includes initial configuration, testing, and verification of multi-PLMN operation, and the later repeated activities with subsequent upgrades for the OBU. These include the link aggregation mode upgrade to the multi-SIM OBU, which previously only operated with the link selection mode. In link selection mode, the OBU continuously monitors different PLMN connections and selects the best one based on pre-configured criteria that includes signal strength, latency, and radio access technology (RAT) priority. On the other hand, the link aggregation mode allows for splitting and simultaneous routing of traffic over the two PLMNs, with inherent redundancy and scalability of capacity due to this link bonding.

The configuration, testing, and verification of the multi-SIM OBUs were carried out in different environments (see Figure 56). This included testing in laboratory environments with indoor 5G coverage, as well as, in-vehicle deployment and testing on the designated test roads for the FI-TS in the AALTO Otaniemi campus.

Figure 56: Testing of the FI-TS multi-SIM OBUs in the lab and in-vehicle

3.4.5.2 Main results

The verification results for the FI-TS multi-SIM OBU solution contributed for agnostic testing in the ES-PT CBC are shown in Table 25. The less than 100% completion of the verification accounts for the fact that there are still some deployment and operational aspects in the ES-PT CBC that will differ from that encountered in the FI-TS where most of the verification activities have been conducted.

Table 25: Verification results for the FI multi-SIM OBU solution contribution to ES-PT CBC

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	6	0	0	0	100%
OBU related issues	4	0	1	0	90%
UE related issues	10	0	1	0	95%
5G network related issues	2	0	0	0	100%
Network handover related issues	1	0	1	0	75%
Network related issues	3	0	1	0	88%
Subtotal: functional issues	13	0	2	0	93%
Logging related issues	5	0	1	0	92%
Total	**18**	**0**	**3**	**0**	**93%**

3.4.5.3 *Next steps*

At the end of February 2022, the agnostic testing of multi-SIM OBU at the ES-PT CBC is still in the planning phase. The next steps include the remote deployment of the backend server (MIP gateway server) closer to the CBC, to ensure optimum performance for the multi-SIM OBU. Prior to the trials in the CBC, some testing will be carried out to verify the correct operation of the multi-SIM in the designated test vehicle and 5G network environment in the ES-PT CBC.

3.5 Local Test Site France

3.5.1 US#1.2: Infrastructure-assisted advanced driving (AssInfrastructure)

3.5.1.1 *Verification process overview*

The infrastructure-assisted advanced driving user story at the FR TS has been pre-tested during 2021. This scenario involves 1 CAV and 1 CV provided by VEDECOM, and a basic vehicle. The tests happened at Satory and the vehicles are connected to 5G NSA networks. The intelligence functionalities required for the advanced manoeuvres are installed on the MEC/Cloud entities. The MEC is based on ETSI architecture and allows integrating applications in the form of VMs or containers. As such, cooperative perception, data fusion, and risk analysis will be integrated on the MEC. VEDECOM has built its own 5G OBUs (2 OBUs) based on the SIMCOM chipset. In addition, VEDECOM has acquired 3 5G OBUs from VALEO. The FR TS contributions to ES-PT are a 5G connected vehicle to test interoperability with ES-PT "local vehicles", and a seamless handover solution based on an intelligent router provided by CATAPULT to carry out handover at the border.

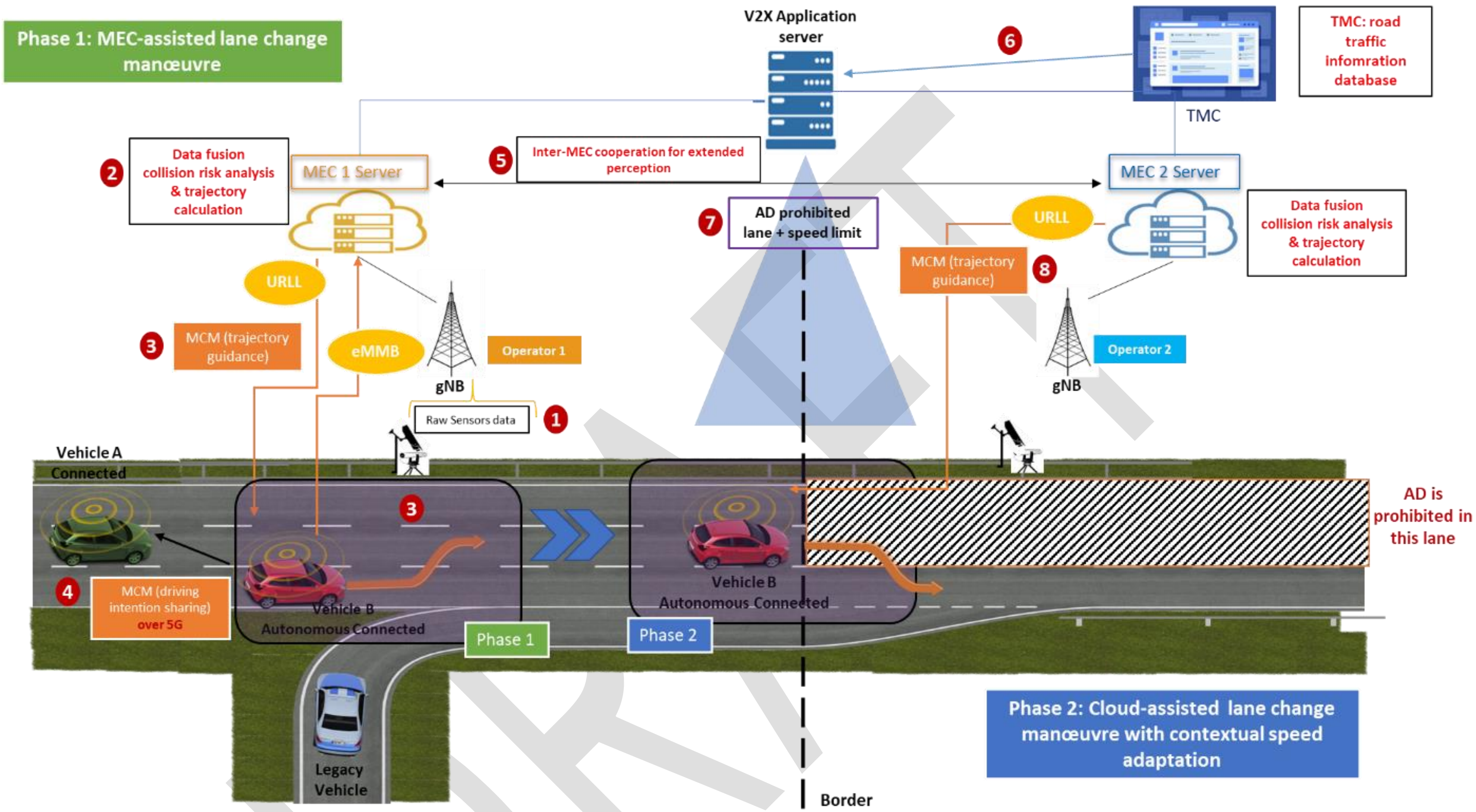

Figure 57: Infrastructure-assisted advanced driving at FR TS

During February 2021, individual components testing has already started through testing cooperative perception, data fusion, and risk analysis functionalities.

During these tests, both the CAV and CV are equipped with a 5G OBU as illustrated by Figure 58.

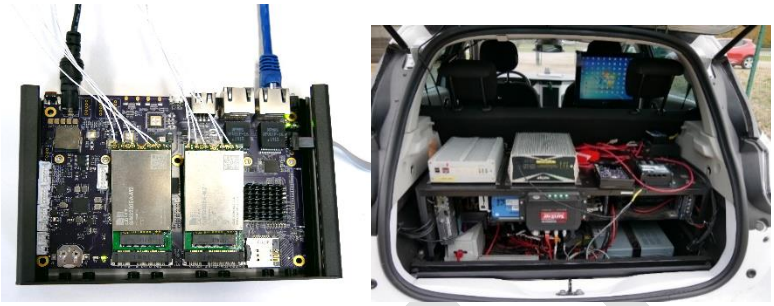

Figure 58: 5G OBU integration in the FR TS CV and CAV

In Figure 59, we illustrate some of the testing activities at the Satory site. The goal was to validate the risk analysis and Manoeuvre coordination algorithms (at the MEC side) with a CAV.

Figure 59: FR TS Pre-testing activities at Satory Site

3.5.1.2 *Main results*

Multiple testing activities have been carried out targeting the US main functionalities tested were collective perception, data fusion, and risk analysis algorithms, in addition to testing the 5G connectivity of the OBU.

Figure 60 shows the test output of 5G connectivity, in which we can verify the connection's status, bandwidth, signal quality, and so on.

```
+CPSI: LTE,Online,208-20,0x77CB,129629704,212,EUTRAN-BAND20,6200,3,3,-99,-892,-605,5
+CPSI: NR5G_NSA,212,NR5G_BAND1,426990,-1030,-120,130
+CPSI: LTE,Online,208-20,0x77CB,129629704,212,EUTRAN-BAND20,6200,3,3,-109,-883,-569,7
+CPSI: NR5G_NSA,212,NR5G_BAND1,426990,-960,-120,130
+CPSI: LTE,Online,208-20,0x77CB,129629704,212,EUTRAN-BAND20,6200,3,3,-99,-878,-604,5
+CPSI: NR5G_NSA,212,NR5G_BAND1,426990,-1020,-120,95
+CPSI: LTE,Online,208-20,0x77CB,129629704,212,EUTRAN-BAND20,6200,3,3,-104,-860,-569,1
+CPSI: NR5G_NSA,212,NR5G_BAND1,426990,-1020,-120,120
+CPSI: LTE,Online,208-20,0x77CB,129629704,212,EUTRAN-BAND20,6200,3,3,-124,-859,-546,3
+CPSI: NR5G_NSA,212,NR5G_BAND1,426990,-1020,-120,110
```

Figure 60: Validation of 5G connectivity of the OBU developed by VEDECOM

We have also tested of the data fusion module, particularly its capacity of building collective perception from information obtained from vehicles and infrastructure sensor and communication units. Thanks to the fine tuned sensor calibration and usage of a high-precision positioning system at the vehicle, the data fusion module can reliably build extended perception. The following figure illustrates the verification output, i.e., results of the data fusion module, correcting perceiving positions of three vehicles used in the test. data fusion module, correcting perceiving positions of three vehicles used in the test.

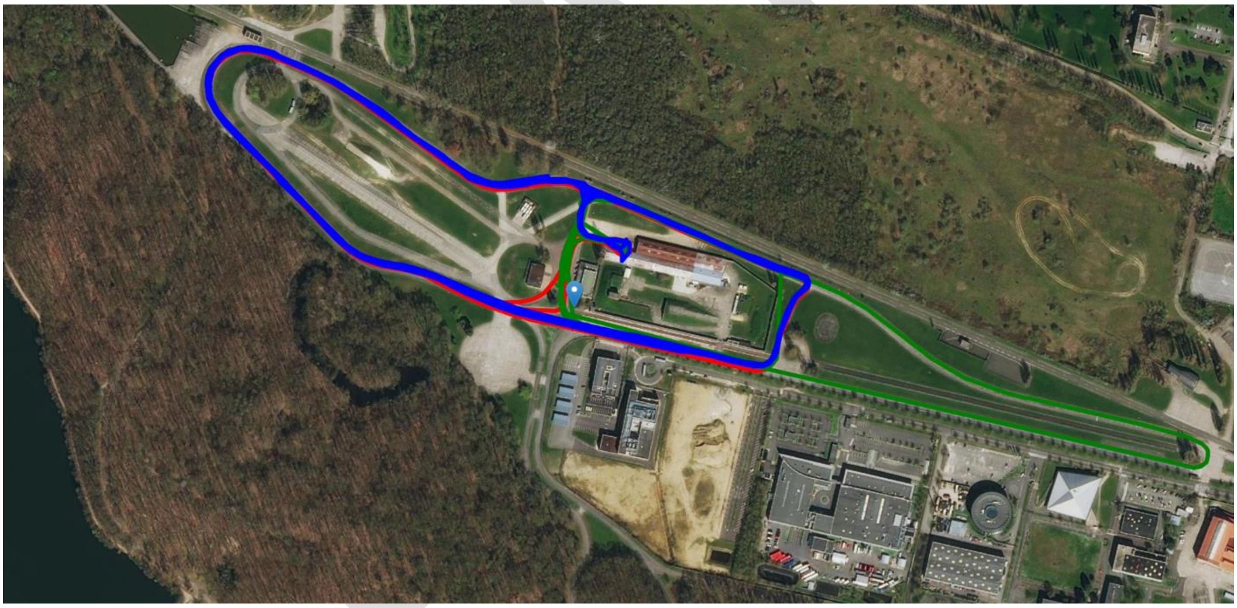

Figure 61: Verification of data fusion and extended perception

Once the extended perception module is validated, we proceeded to validate the risk assessment module. Figure 62 shows the test output of the risk analysis module: time to intersection for the vehicle on the insertion line (red), the minimum post encroachment time predicted between the vehicle on the insertion lane and the CAV on the main road section, and the number of vehicles to which MCM have been sent (green, 1 or 2 depending on the number of vehicles on the main road).

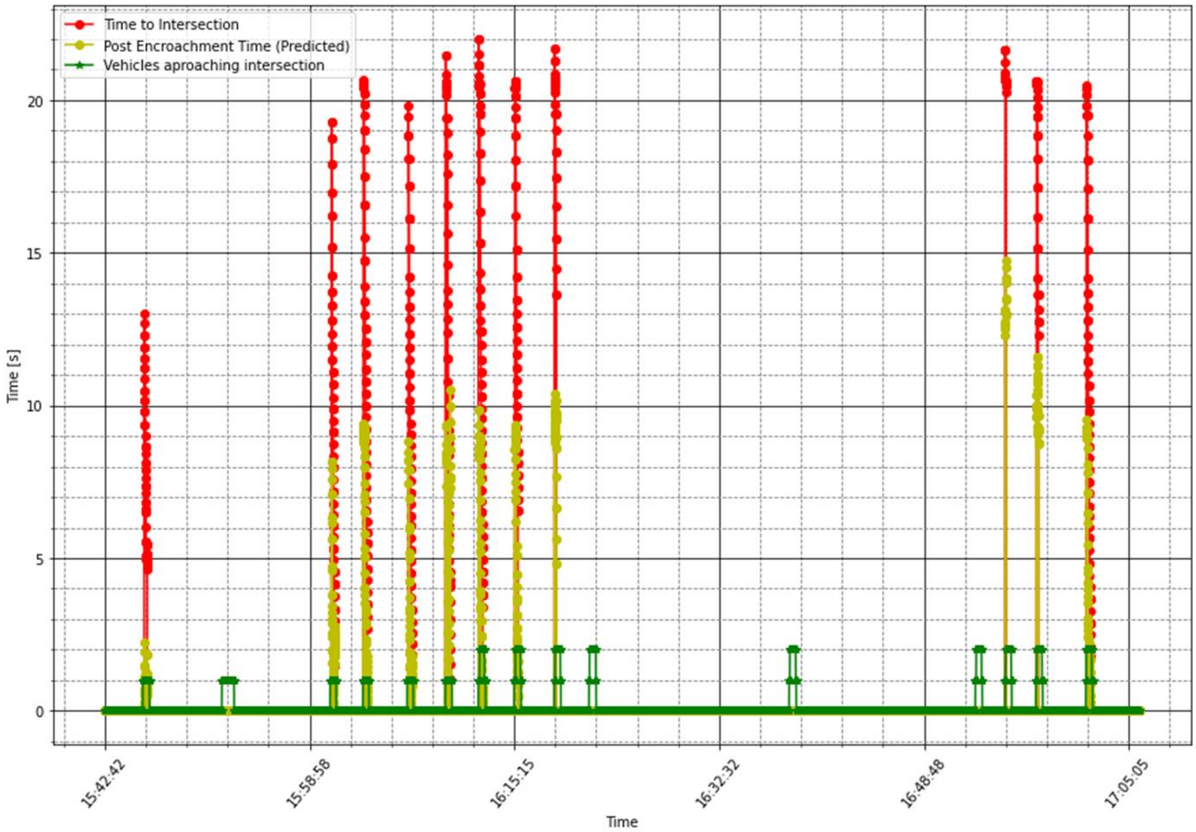

Figure 62: Verification of risk analysis module

Finally, Figure 63 depicts the processing overhead (in ms) of the above modules during the 16 tests. The figure shows that the collective perception would need approximately 20 ms of processing time, while the risk assessment module would give a sudden increase of the resource utilisation at the MEC. It should be noted that the modules are developed in a test platform, RTMaps, and hence we expect that when the application is deployed in real systems, there should be efforts to reduce the processing overhead.

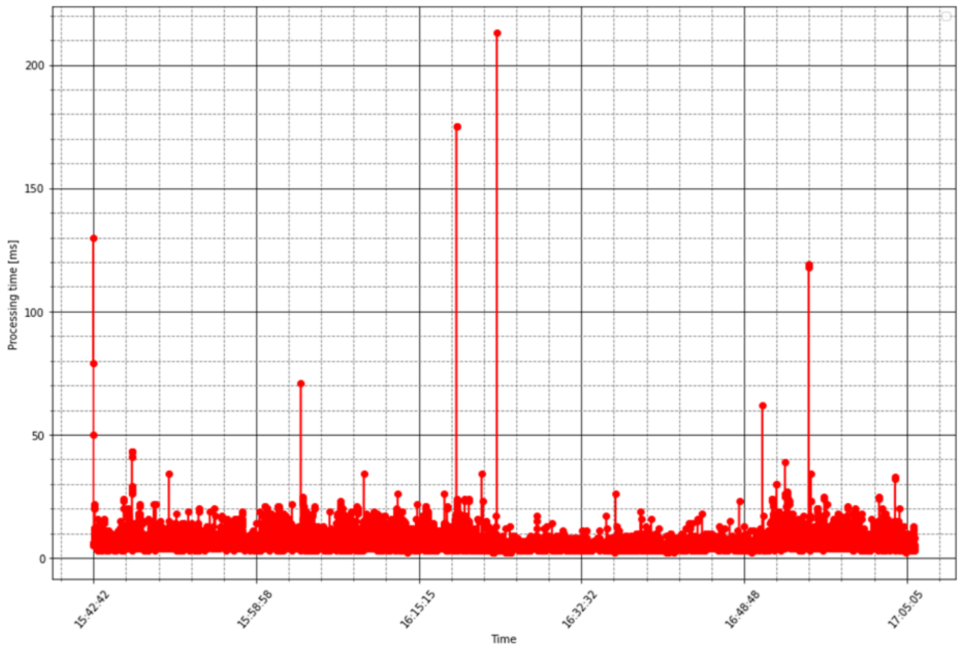

Figure 63: Processing time at the infrastructure for tasks of perception and risk analysis

Table 26 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.1.3): The majority of the tests have been carried out except those related to the mmWave network and OBUs. The tests on mmWave will be carried out in March and April of 2022.

Table 26: Verification results for the Infrastructure-Assisted Advanced Driving user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	8	0	0	0	100 %
OBU related issues	6	0	3	0	83 %
Infrastructure related issues	4	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	23	0	3	0	94 %
5G network related issues	6	0	1	0	93 %
Network handover related issues	2	0	0	0	100 %
Network related issues	8	0	1	0	94 %
Subtotal: functional issues	34	0	1	0	94 %
Privacy and security issues	2	0	0	0	100 %
Logging related issues	5	0	1	0	92 %
Total	**38**	**0**	**5**	**0**	**94 %**

3.5.1.3 Next steps

In the next phase of testing activities, we will focus on 5G mmWave.

3.5.2 Contribution to ES-PT CBC: 5G connected vehicle

3.5.2.1 Verification process overview

The verification for this contribution has already been completed at the local site. The vehicle is installed with 5G OBU, with a V2X protocol stack, a KPI, and a predictive QoS agent developed by the FR TS. The 5G connectivity of the OBU, V2X message formats, and application behaviours have been tested in France, validating their correct functions. The messages interoperability with the ES-PT CBC is ensured by using the same V2X message versions (CAM, CPM) and interoperability tests between FR TS and ES-PT CBC protocol stacks. Particularly, ES-PT CBC sent already encoded CAM and CPM messages, and FR TS decode the messages and send the results to ES-PT. The same verification procedures have been made for messages already encoded by the FR TS protocol stack. Technical discussions and validation of codes have also been carried out between FR-TS and ES-PT for the MQTT connection and MEC handover.

Finally, the 5G connectivity of the FR TS connected vehicle at the ES-PT connected vehicle will be tested at the corridor during Q1 of 2022, as soon as the vehicle received an authorisation to run on the road by the Spanish road operator.

3.5.2.2 Main results

The FR TS site has tested in France the functionalities of the connected vehicle including 5G connectivity, V2X message transmissions, and receptions, and the functionality of the KPI measurement tool. The following shows the results of data rate different message types: CAM, CPM, and MCM.

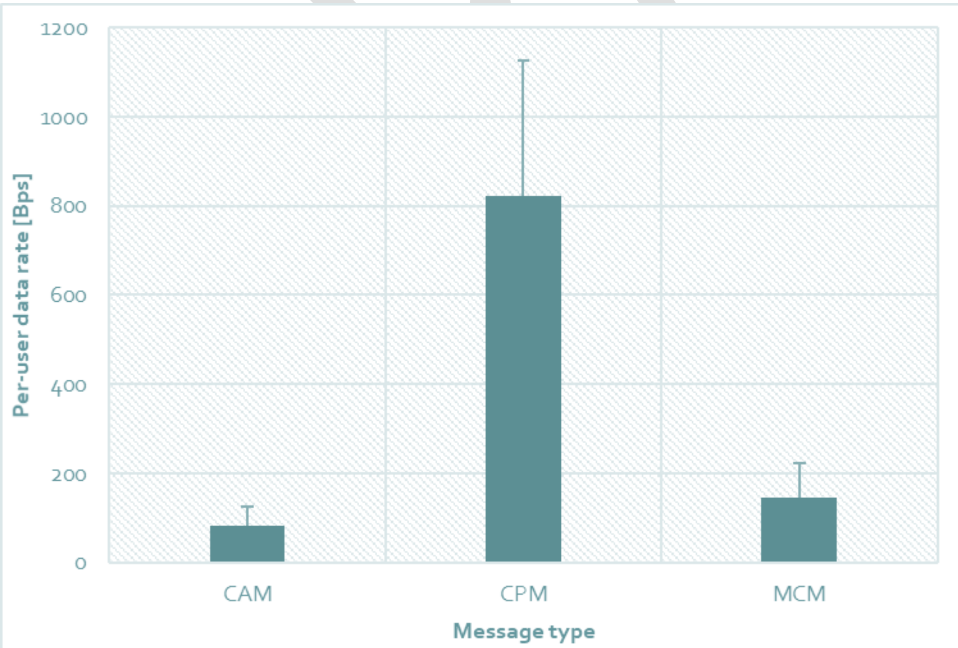

Figure 64: Per-user data rate for CAM, CPM, and MCM messages

Table 27 gives an overview of the checklist testing status. The tests at the local site and remote-interoperability tests have been successfully carried out. The next step is to conduct a test and validation at the ES-PT corridor as planned in March 2022.

Table 27: Verification results for the 5G connected vehicle user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	8	0	0	0	100 %
OBU related issues	7	0	2	1	89 %
UE related issues	15	0	2	0	94 %
5G network related issues	0	0	0	1	0 %
Network handover related issues	0	0	0	3	0 %
Network related issues	0	0	0	4	0 %
Subtotal: functional issues	15	0	2	4	76%
Logging related issues	4	0	1	1	75 %
Total	**19**	**0**	**5**	**5**	**74 %**

3.5.2.3 Next steps

The next step will be to bring a connected vehicle to the ES-PT site, validate its connectivity to the ES-PT 5G networks, and contribute to the trials of the ES-PT advanced driving use case.

3.5.3 Contribution to ES-PT CBC: Multi-SIM OBU solution

3.5.3.1 Verification process overview

The intelligent router has already been tested at VEDECOM and CATAPULT premises. The router is capable of carrying out seamless transfer between 4G and 5G connections, 5G and 5G connections. DEKRA tools have been used to measure the performances of TCP/UDP data flows. Besides TCP/UDP flows, video streaming has been used to validate the impact of the solution on video quality.

Figure 65 illustrates the graphical interface of the intelligent router that allows the progress of the test, status, and data rate (if connected) of individual interfaces.

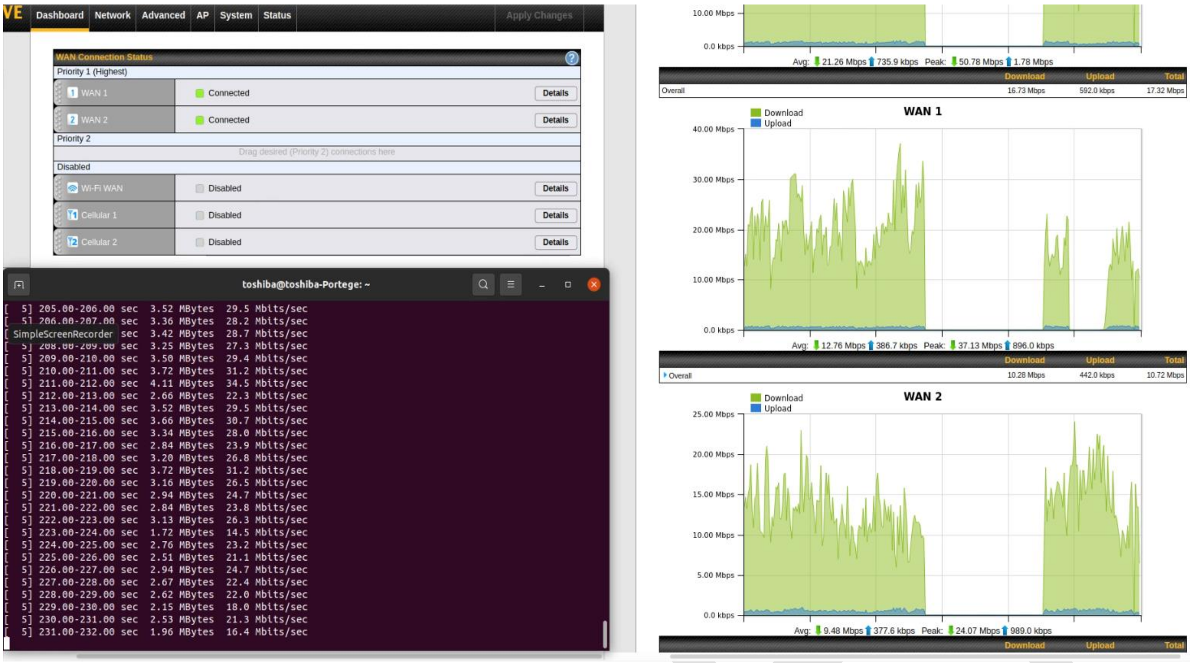

Figure 65: Graphical interface of the intelligent router to verify the multi-SIM solution

The following figure shows the screen shot of the transmitted and received video images during disconnection from the first PLMN (while the connection to the second PLMN has been established)

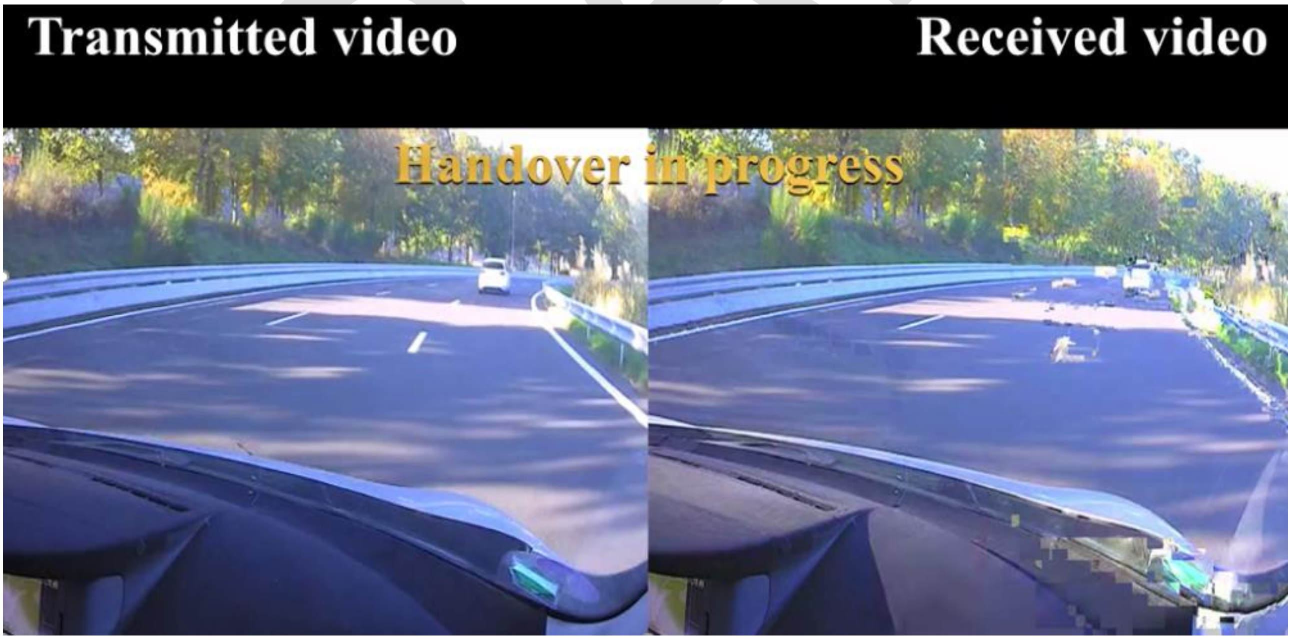

Figure 66: Validating Multi-SIM solution using video data

3.5.3.2 *Main results*

We have verified delay and packet loss performances of the multi-SIM solutions for UDP and TCP traffics as shown in the following figures. The results show that the delay penalty for UDP and TCP traffic are 30 ms and 150 ms respectively. On the other hand, the loss penalty is between 1% to 6%.

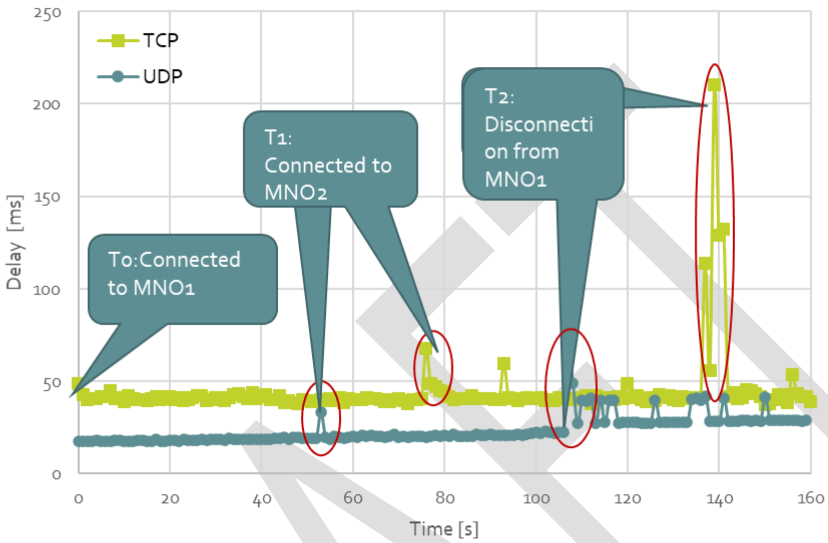

Figure 67: Delay performance of the Multi-SIM solution

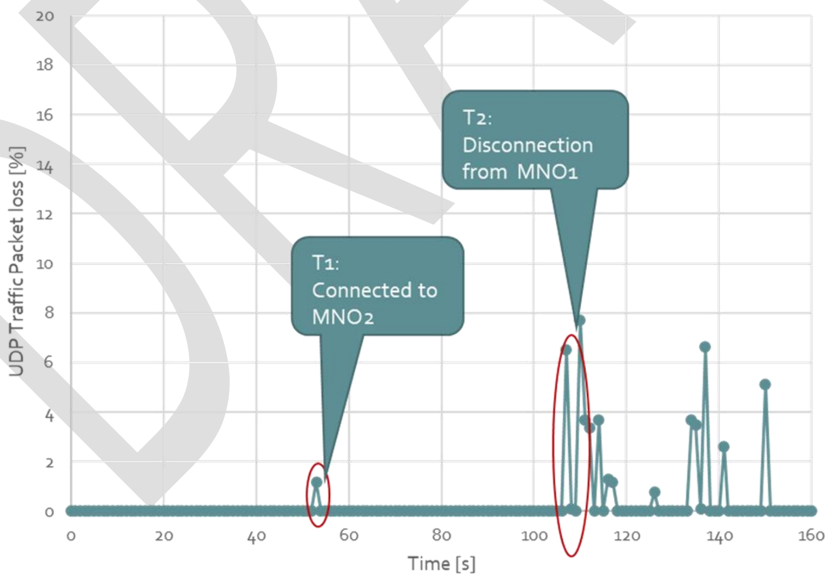

Figure 68: Packet loss results of multi-SIM solution

Table 28 gives an overview of the checklist testing status. The tests at the local site have been successfully carried out. The next step is to conduct test and validation at the ES-PT corridor as planned in March 2022.

Table 28: Verification results for the Multi-SIM OBU solution user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	7	0	0	0	100 %
OBU related issues	4	0	2	0	83 %
External servers	3	0	2	0	80 %
UE related issues	14	0	4	0	89 %
Network handover related issues	0	0	1	0	50 %
Network related issues	0	0	1	0	50 %
Subtotal: functional issues	14	0	5	0	87 %
Logging related issues	4	0	1	1	75 %
Total	**18**	**0**	**6**	**1**	**84 %**

3.5.3.3 Next steps

The next step will be to bring the multi-SIM solutions to the ES-PT site, and conduct tests and benchmarking with FI TS and ES-PT CBC.

3.6 Local Test Site Netherlands

3.6.1 US#1.3: Cooperative collision avoidance (CoCA)

3.6.1.1 Verification process overview

The Cooperative Collision Avoidance (CoCA) use case is developed by VTT in Finland and will be trialed in the Dutch trial site. In the Dutch trial, the CoCA scenario involves 2 vehicles, a CAV from VTT ("Martti") and a CV from TUE, which are connected with, respectively, the SA networks of TNO and KPN, and a Manoeuvre Coordination Service (MCS) application installed on the KPN MEC. The original plan was to integrate the CoCA functionality into the TUE CV vehicle. However, as for the MCS application in the ES-PT CBC, VTT will provide a "standalone" OBU to be installed in the CTAG vehicles, the same OBU was decided to be used in the CoCA application. The "standalone" OBU consists of a laptop, 5G modem, and GNSS receiver (Figure 69).

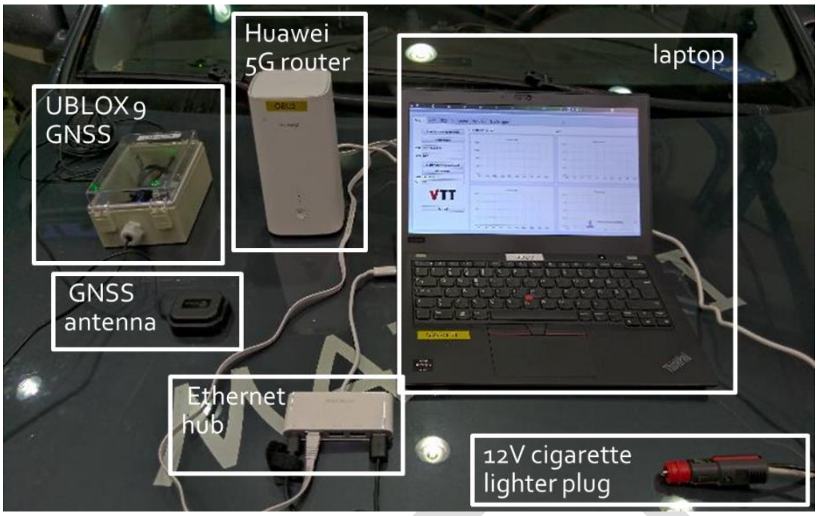

Figure 69: VTT OBU for CoCA tests, consisting of laptop, GNSS, and 5G router

The CoCA application was first tested in a test track in Pirkkala near Tampere, in a commercial 4G network. In these tests, the logic of the application was tested, using two vehicles from VTT: a CAV and a motorcycle, equipped with the 5G OBU (Figure 70). The MCS application was installed in a mobile roadside unit. The tests were successful.

Figure 70: Left: CoCA tests in Pirkkala with CAV and connected motorcycle. Right: display on the motorcycle showing the warning from the CoCA application

The actual trial takes place at a parking lot near the A58 highway in Vaarle, between Helmond and Eindhoven. As due to COVID-19, travelling to the Netherlands was not possible in the first half of 2021, two OBUs were sent to TNO for performing remote verification tests, to do the rest of the verification tests. The 5G module from Huawei, which was tested in Finland on a commercial 5G network, and according to specifications, supports 5G SA, could not connect to the local test networks, and was replaced with Netgear modems, which were tested in the SA networks by TNO.

3.6.1.2 *Main results*

Table 29 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.1.4):

Table 29: Verification results of the CoCA user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	9	0	0	0	100 %
UE related issues	18	0	0	0	100 %
5G network related issues	8	0	0	0	100 %
Network handover related issues	1	0	0	0	100 %
Network related issues	9	0	0	0	100 %
Subtotal: functional issues	27	0	0	0	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	4	0	1	1	75 %
Total	**32**	**0**	**1**	**1**	**96 %**

The functionality is working, and trials have been performed in the Netherlands. The only issues raised are due to logging, as there are some discrepancies between the uniform format and the format used for logging during the tests, and these issues will be corrected manually after performing the tests in the Netherlands.

3.6.1.3 *Next steps*

Trials were performed in September 2021 in the Netherlands, when the highway parking in Vaarle was closed from other traffic. Based on the collected information, the KPIs are calculated and the data is then transferred to the CTS.

3.6.2 US#3.5: Extended sensors with CPM messages (CPM)

3.6.2.1 *Verification process overview*

The Extended Sensors (ExSe) use case involves two vehicles, one CV from TNO and one CV from Siemens (see Figure 71).

These vehicles both have 5G SA capable OBUs integrated, which are developed by TNO. Also, a roadside camera system from Siemens is used in the use case. The Siemens vehicle and Siemens' camera system will detect objects (vehicles) on the A270 highway. This data is used by the TNO vehicle to direct a safe lane change or highway merge. The raw camera data is processed by the VBM system. These detections are sent to an MQTT edge-server by utilizing slicing in the 5G SA network. These detections are sent as ETSI CPM messages. The Siemens vehicle will be connected to the KPN network, the TNO vehicle will be connected to the TNO network. Hence, an edge-interconnect infrastructure (MQTT federation) has been developed and deployed. The edge-interconnect has been verified to be working with application data from the ExSe use case.

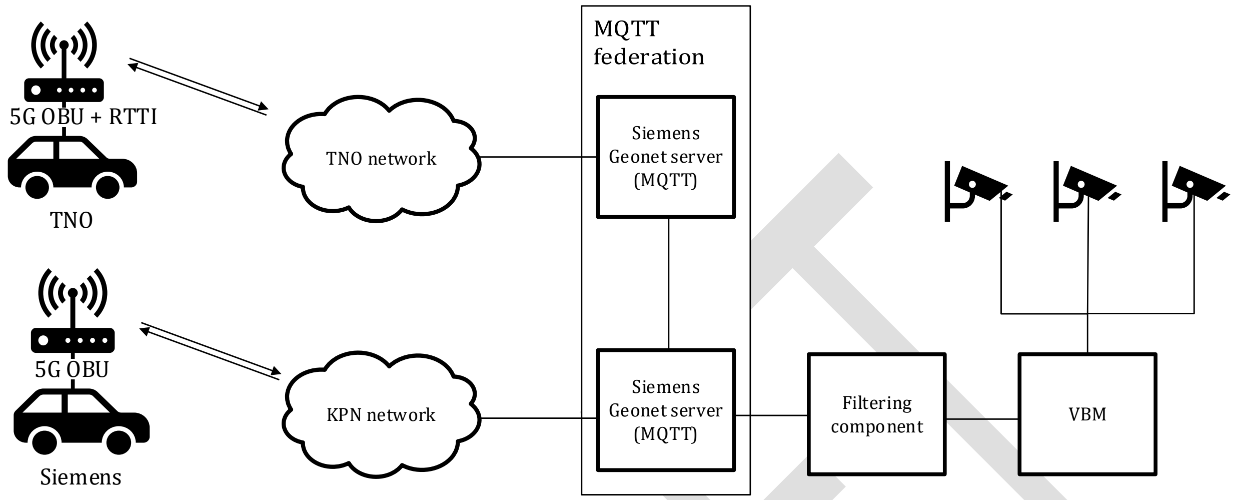

Figure 71: Deployed architecture in the CPM user story

First tests in Q4 2020 showed that the detections from the camera system were too inaccurate and jittery to work with. So, a filtering algorithm has been developed and deployed on the roadside. Currently, this filtering algorithm is already helping us in achieving more accurate predictions on vehicle positions from the camera system, but the algorithm still needs some additional fine-tuning.

An HMI Android application has been developed: Real Time Traffic Information (RTTI) to present the driver of the TNO vehicle with advice on when and how to merge and/or do a lane change. These advices consist of speed advice and an indication on when a merge or lane change is considered safe to do so. Figure 72 shows a screenshot of the HMI: red dots on the map show the vehicle detections, the blue dot shows the targeted merge position relative to the detected vehicles. The red bar shows the maximum allowed speed, the white bar shows the current vehicle speed. The green bars show the advised speed as a window to make the merge or lane change. The merging/lane changing application itself, which generates the advice, runs on the OBU. The application has been verified to be successfully working in a controlled environment. But, as stated above, the filtering of the detections on the road need some additional work. Currently, to cope with the inaccurate detections from the camera system we use the CPM detections from the Siemens vehicle as the only source of object-information.

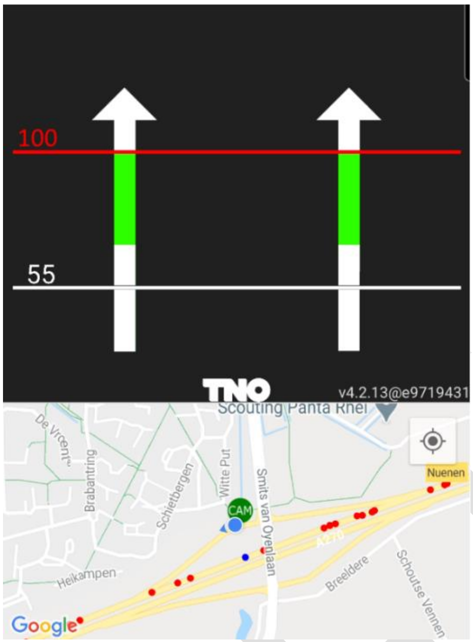

Figure 72: Screenshot from the RTTI HMI application

3.6.2.2 Main results

Table 30 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.3.7):

Table 30: Verification results of the CPM user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	2	0	0	0	100 %
OBU related issues	7	0	0	0	100 %
Infrastructure related issues	4	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	18	0	0	0	100 %
5G network related issues	6	1	0	0	86 %
Network handover related issues	1	0	0	2	33 %
Network related issues	7	1	0	2	70 %
Subtotal: functional issues	25	1	0	2	89 %
Privacy and security issues	3	0	0	0	100 %
Logging related issues	6	0	0	0	100 %
Total	**34**	**1**	**0**	**2**	**92 %**

The failed test represents verification N4. The network from TNO is not able to stretch across the full geographical area of the use-case. This is solved by splitting the use case into two scenarios: a lane changing scenario and a lane merging scenario. The lane merging scenario will be driven with the KPN network only, the lane changing scenario will be driven with both KPN and TNO networks and can be used for network scenario's such as edge-interconnects and handovers between the networks (Figure 73).

Furthermore, all static network tests have been successfully completed.

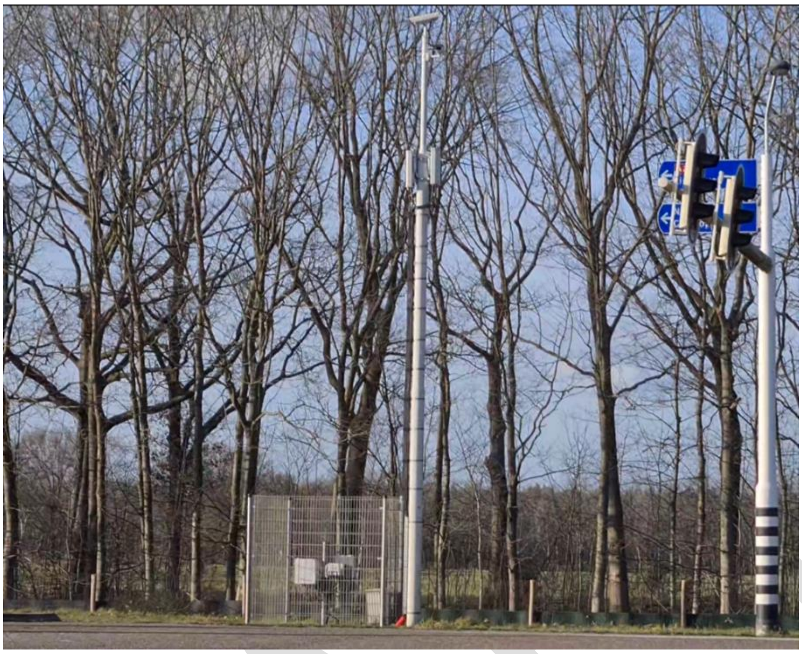

Figure 73: TNO's 5G SA setup at Neervoortse Dreef

3.6.2.3 *Next steps*

While the static scenarios for testing the 5G SA network's capabilities and stability were successfully verified, dynamic scenarios prove to be more difficult for existing implementations of UE's. Especially recovering a connection after a connection loss is difficult with the current generation of 5G SA UE's. Further development and testing are needed on this topic together with UE suppliers.

3.6.3 US#4.3: Remote driving using 5G positioning (5GPositioning)

The remote driving tests are split into two separate verification and tests: remote driving functionality on pre-commercial 5G network from KPN and positioning tests on a pre-development mm-wave based network from TU/e.

3.6.3.1 *Verification process overview*

Early remote driving functionality tests took place in January 2020, testing both the SISSBV and TU/e remote station and SISSBV and TU/e vehicle on the same KPN network and showcasing this in a demo during the KPN 5G FieldLab event in Helmond. During the project review on 3 December 2020, KPN, TU/e, SISSBV, AIIM and associate partner Roboauto, showed a working demo, using 1 remote station and 2 vehicles over the KPN 5G SA network, proving the remote driving function to be working as expected and integration of the OBU in the vehicles to be ready. A video recording can be found on the 5G-MOBIX website, showing the results. See also Figure 74 (upper left: SISSBV vehicle (inside); upper right: TU/e-AIIM vehicle (inside, being remotely driven); lower left: TU/e-AIIM vehicle (outside); lower right: SISSBV remote station):

Figure 74: Screenshot of TU/e-AIIM and SISSBV vehicles remotely driven over KPN 5G SA network during PO review 3 December 2020

Further verification testing on integration with virtual vehicle (for testing with increased network latencies) has been done in March 2021. Figure 75 shows one of these tests using different network configurations: with zero ms latency (left) and another with 20 ms delay and 2% packet loss (right).

Figure 75: Testing remote driving with virtual environment

In parallel, TNO is working on the TNO network which is required for handover testing, and TU/e is working on their own network for positioning. This has all been separated from each other to ensure trials can continue according to plan.

3.6.3.2 Main results

Tests have been executed on the KPN network mainly, on both ACNL as well as Vaarle testing grounds (see section above). Two remote stations and two vehicles are successfully connected and tested on both locations, showing the workings of the KPN network and OBUs successfully.

In January 2021, additional tests were conducted to also verify the connection between TU/e remote station and both vehicles over the KPN network (see Figure 76).

Figure 76: TestingTesting with AIIM-TU/e vehicle on KPN 5G network, using TU/e remote station

Vehicles function as expected, with some minor tuning required for AIIM-TU/e vehicle.

Table 31 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.4.3):

Table 31: Verification results of the 5G Positioning user story

Group	Basic version: Remote driving					Full version: 5G positioning				
	Pass	Fail	Partly	Not tested	Completion %	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %	9	0	0	0	100 %
OBU related issues	9	0	0	0	100 %	5	0	4	0	78 %
External servers	5	0	0	0	100 %	5	0	0	0	100 %
UE related issues	23	0	0	0	100 %	19	0	4	0	91 %
5G network related issues	3	0	0	0	100 %	2	0	1	0	83 %
Network handover related issues	0	0	0	2	0 %	0	0	0	2	0 %
Network related issues	3	0	0	2	60 %	2	0	1	2	50 %
Subtotal: Subtotal: functional issues	26	0	0	2	93 %	21	0	5	2	84 %
Privacy and security issues	2	0	0	0	100 %	2	0	0	0	100 %
Logging related issues	6	0	0	0	100 %	2	0	4	0	67 %
Total	**34**	**0**	**0**	**2**	**94 %**	**25**	**0**	**9**	**2**	**82 %**

Only 2 tests are set to "not tested", since handover testing between KPN and TNO networks is not able to be executed, since that functionality is not yet available.
Testing on positioning using the mm-wave network is separately developed, the mm-wave network is tested in the lab environment currently and a test setup for testing outside is under development. This will

be tested separately from the rest of the trial testing since components for testing on KPN networks are already working as expected. Because of the development of the TU/e network, trails have been split up, in order to not delay the pre-trials and make use of the vehicles and remote stations on the KPN network.

3.6.3.3 Next steps

Trials on the KPN network have been successfully executed in April 2021 and September 2021 on Vaarle parking, including gathering drive and network related data according to the 5G-MOBIX standards. Further development and deployment of the TU/e network is on-going and planned for Q3-2022 for the positioning trials, where the developed mm-wave OBU (already tested in the lab) will be tested outside.

3.6.4 Contribution to ES-PT CBC: Overtaking / MCS application

3.6.4.1 Verification process overview

The MCS Application was verified in Autumn 2021. For the verification, the user story, which involves 3 vehicles, is split into 2 scenarios with 2 vehicles:

1. overtaking a slow-moving vehicle (without vehicle approaching at higher speed in the left lane)
2. faster vehicle approaching the blind spot on the left lane. The ego-vehicle changes lane when the faster vehicle has passed.

These two scenarios were tested by VTT in Pirkkala, using the instrumented vehicle Martti and the connected motorcycle (Figure 70). The slow-moving vehicle overtaking scenario was also tested at Vaarle in conjunction with the CoCA tests, but due to a vehicle breakdown, not all planned tests could be performed.

The first plan was to ship the 2 OBUs, which were used for the CoCA user story verification and trial in the Netherlands, to Spain for the MCS verification. Due to delays in the verification, 2 new OBUs were prepared and shipped. The OBU included Huawei CPE modems, which were tested in various 4G and 5G test networks in Finland. However, the Huawei modems could not be connected to the 5G test network in Spain, due to an issue with APN settings. At the visit of VTT personnel in October to the CBC, the modem was replaced with a locally purchased Xiaomi Mi 11 phone. After that, the exchange of messages was tested remotely from the VTT offices.

In November, prior to the planned trials, also the Netgear modems, which were used for CoCA trials in the Netherlands, were tested, but their performance was poor compared to the Xiaomi, and hence a second Xiaomi phone was purchased. A difference was noticed in the behaviour of the 2 SIM cards, and one of the SIM cards was changed. Handover and roaming could not be tested, as the devices could not connect to the Portuguese network.

3.6.4.2 *Main results*

Table 32 shows the results of the verification:

Table 32: Verification results of the contribution of the Dutch trial site to the ES-PT CBC

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	1	0	0	0	100 %
OBU related issues	7	0	1	0	69 %
UE related issues	8	0	1	0	94 %
5G network related issues	7	0	0	0	100 %
Network handover related issues	0	0	0	2	0 %
Network related issues	7	0	0	2	78 %
Subtotal: functional issues	15	0	1	2	78 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	4	0	1	1	83 %
Total	**20**	**0**	**2**	**3**	**84 %**

The application has been verified in the ES-PT CBC in November 2021, but the modems could not connect to the Portuguese network, and handover and roaming issues were not yet solved at that moment. . There are some minor issues with the logging formats, and upload to the CTS will be performed manually after the tests.

3.6.4.3 *Next steps*

The verification tests, as well as the trials, will continue when handover and roaming work in the ES-PT CBC in mid March 2022. The VTT team will then make a second trip to the ES-PT CBC to perform the rest of the verification test and collect the data for the evaluation.

3.7 Local Test Site China

3.7.1 US#1.4: Cloud assisted advanced driving (CloudAssisted)

3.7.1.1 *Verification process overview*

The Cloud assisted advanced driving (CloudAssisted) use case is developed by DUT and SDIA in China and will be trialled in the Jinan highway trial site. In the Jinan highway trial, the site has installed a 2-kilometer road with 5G infrastructure, and SDIA has already installed three 5G base stations in the east zone. In this test, the CloudAssisted scenario involves 2 vehicles, a CAV from SDIA and a CV from SDIA. The plan is to integrate the CloudAssisted functionality in the SDIA vehicle and CNHTC CV. The test vehicles consist of 5G modems, 5G OBUs, and GNSS (Figure 77).

Figure 77: The test vehicles with 5G modems, 5G OBUs, and GNS in CN site

3.7.1.2 Main results

Table 33 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.1.5).

Table 33: Verification results of the CloudAssisted user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	8	0	0	0	100 %
Infrastructure related issues	5	0	0	0	100 %
External servers	5	0	0	0	100 %
UE related issues	27	0	0	0	100 %
5G network related issues	6	0	0	0	100 %
Network handover related issues	1	0	0	0	100%
Network related issues	7	0	0	0	100 %
Subtotal: functional issues	34	0	0	0	100%
Privacy and security issues	1	0	0	0	100 %
Logging related issues	3	0	2	1	67 %
Total	**38**	**0**	**2**	**1**	**95 %**

One test is marked as "Not tested". Due to COVID-19, travelling to the SDIA is not easy. The required logging components and physical components integration are in progress. Sixteen tests are set to "Not relevant". For example, the GNSS positioning is not relevant because GPS/BeiDou component is employed for positioning, and the VRUs are not relevant because other end user devices are not considered in the User Story.

3.7.1.3 Next steps

The dual sim and satellite testing have been carried out, and a full chain pre-testing of the CN TS user story was made. In the next phase of pre-testing activities, we will focus on logging and uploading the data which is the on-board computer of vehicle and cloud server for controller message (e.g. vehicle data, sensor data). In addition, the validity of the timestamps in the logs will be verified completely.

3.7.2 US#2.3: Cloud assisted platooning (AssCloud)

3.7.2.1 Verification process overview

In the Cloud assisted platooning US, two vehicles are provided by CNHTC (the leading vehicle, and the following vehicle) (Figure 78). In CN TS, the leading vehicle processing Cooperative Routing Messages (CRMs) are received from one cloud server, which provides routing planning for the platoon. The vehicles exchange information to give the correct commands to the follower vehicle.

Figure 78: The truck in the platooning in CN site

3.7.2.2 Main results

Table 34 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.2.4).

Table 34: Verification results of the AssCloud user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	7	0	0	0	100 %
Infrastructure related	6	0	0	0	100%
External servers	5	0	0	0	100 %
UE related issues	27	0	0	0	100 %
5G network related issues	2	0	0	0	100 %
Network handover related issues	1	0	0	0	100%
Network related issues	3	0	0	0	100 %
Subtotal: functional issues	30	0	0	0	100 %
Logging related issues	3	0	2	1	67 %
Total	**33**	**0**	**2**	**1**	**94 %**

DATANG provides the OBUs, and CNHTC currently is integrating them with their vehicles. SDHS has tested the connection and accessibility of the device and the servers. Related messages were logged at the onboard computer in the vehicles. And logging in on-board computer of vehicle and cloud server for controller message has been tested. Tests with "partly" and "not tested" results are mainly linked to the unavailability of CN_veh_04, 5G OBU, and required components. Tests with "not relevant" result are due to the unavailability of MEC.

3.7.2.3 *Next steps*

In the next phase of pre-testing activities, we will focus on logging and uploading the data which is the on-board computer of vehicle and cloud server for controller message (e.g. vehicle data, sensor data). In addition, the validity of the timestamps in the logs will be verified completely.

3.7.3 US#4.4: Remote driving with data ownership focus (DataOwnership)

3.7.3.1 *Verification process overview*

The tested vehicle is provided by SDIA, which equipped DATANG OBUs. The local test site in SDIA has deployed 5G Infrastructure with a full 5G SA covered. The cloud server is supported by SDIA and the application on the server is still tested by DUT. We have tested the video transmission from the vehicle to the cloud server, as shown in Figure 79.

Figure 79: Testing with video transmission on 5G SA network in Jinan, China

3.7.3.2 *Main results*

Table 35 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.4.4):

Table 35: Verification results of the DataOwnership user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	7	0	1	0	100 %
External servers	5	0	0	0	100 %
UE related issues	21	0	0	0	100 %
5G network related issues	5	0	0	0	100 %
Network handover related issues	1	0	0	0	100%
Network related issues	6	0	0	0	100 %
Subtotal: functional issues	27	0	0	0	100 %
Privacy and security issues	1	0	0	0	100 %
Logging related issues	3	0	2	1	67 %
Total	31	0	2	1	94 %

We have developed and tested the data transmission application for server, edge, and vehicles. But we have not optimized the application to get lower latency. Additionally, logging in the on-board computer of vehicle and cloud server for controller messages has been tested. Currently, we are fully investing in vehicle integration. The applications in the OBU from DATANG were tested in Shanghai, the exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy). All finished work performed well as expected.

3.7.3.3 Next steps

In the next phase of pre-testing activities, we will focus on logging and uploading the data which is on-board computer of vehicle and cloud server for controller message (e.g. vehicle data, sensor data). In addition, the validity of the timestamps in the logs will be verified completely.

3.8 Local test site Korea

3.8.1 US#4.5: Remote driving using mmWave communication (mmWave)

3.8.1.1 Verification process overview

The remote driving using mmWAVE communication use case is developed by KATECH, ETRI, and SnetICT in South Korea and will be tested and validated on the Korean trail site. In the Korean trail site, 1 remote-controlled vehicle (Renault Arkana) is provided by KATECH and Renault Samsung Motors, the mmWAVE OBU and RSU are provided by ETRI, and the mmWAVE Core network is provided by SNetICT.

The test vehicle equips 8 cameras (4 cameras for around, 4 cameras for the front, left, right and rear view) to stream real-time video to the remote site (Figure 80). All the vehicle status and sensing acquisition data is aggregated by the vehicle gateway and will be transferred to the remote server via a wireless communication link (Wi-Fi, LTE, and mmWAVE). In addition, in the remote site, vehicle control data is transferred to the Remote Control Vehicle (RCV) in real-time.

Figure 80: Test vehicle setup for remote driving using mmWAVE communication

The remote driving using mmWAVE communication is tested in the ETRI's test lab and remote driving using Wi-Fi and LTE communication is tested in the KATECH's private proving ground and all the remote driving functionality is well tested and validated successfully in the early trial phase (Figure 81).

(a) Remotely controlled vehicle via wireless communication by remote controller in remote site

(b) Remote controller in remote site connected with RCV via wireless communication

Figure 81: Early trial for remote driving using wireless (Wi-Fi and LTE) communication

In the second test phase (October, 2021), remote driving using mmWAVE communication was tested in the ETRI's test road and most of the remote driving functionality is well tested and validated successfully in terms of control data transmission (from the remote server to remote control vehicle; downlink) and vehicle status and video streaming (from remote control vehicle to the remote server; uplink) sharing.

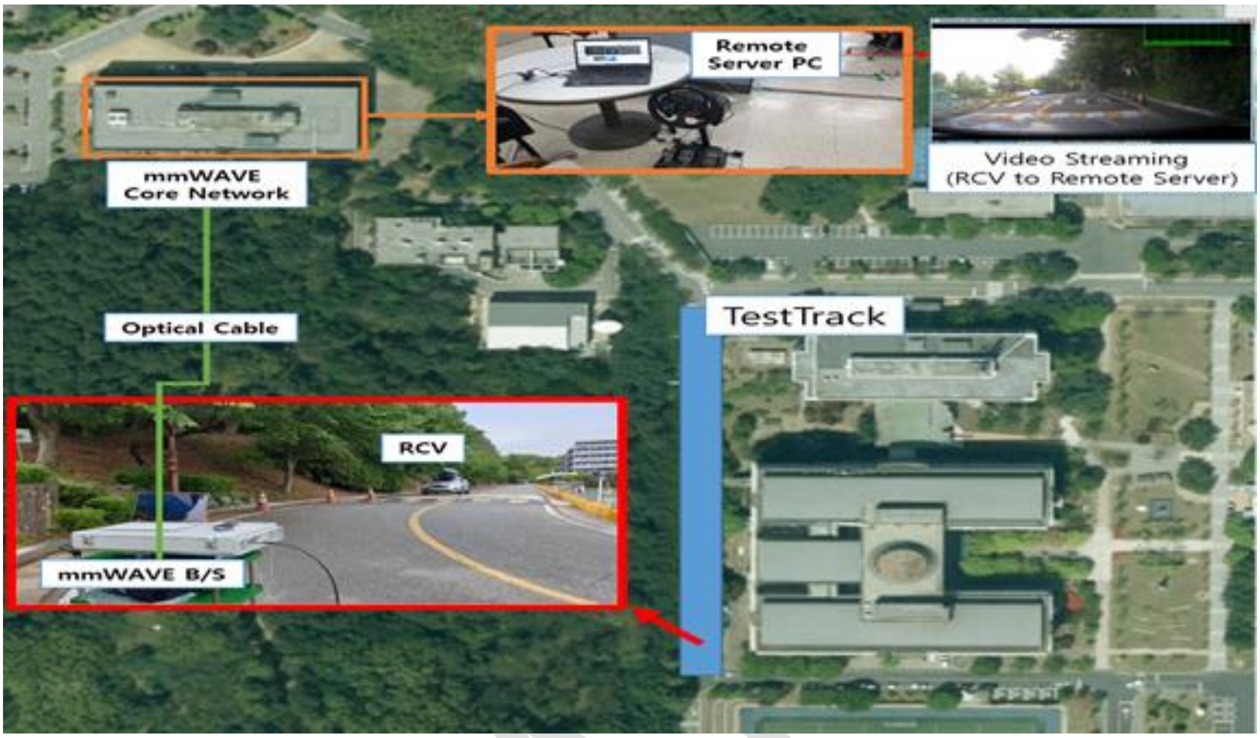

Figure 83: ETRI's test track with mmWAVE communication

3.8.1.2 *Main results*

Table 36 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.4.5):

Table 36: Verification results of the remote driving user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	9	0	0	0	100 %
OBU related issues	5	0	0	0	100 %
Infrastructure related issues	1	0	0	0	100 %
External servers	3	0	1	0	100 %
UE related issues	19	0	0	0	100 %
5G network related issues	2	0	0	0	100%
Network handover related issues	0	0	0	0	0 %
Network related issues	0	0	0	0	0 %
Subtotal: functional issues	21	0	0	0	100 %
Privacy and security issues	2	0	0	0	100 %
Logging related issues	5	0	0	0	100 %
Total	**28**	**0**	**1**	**1**	**96.55 %**

During the trial, it was observed that all the functionalities work as expected, which allowed us to successfully demonstrate and validate the main objectives in which the L4 remote controlled vehicle is controlled via mmWave connection.

3.8.1.3 Next steps

Since the field test was done successfully, showing that the overall functionalities work properly, no further actions are required for future field trials. Nevertheless, we'll continue to work on the additional functional testing and system stabilization.

In the next phase of testing activities that are scheduled in early March 2022, the mmWAVE infrastructure (base station, core network, and OBU) will be fully integrated, tested, and validated at the KATECH's proving ground. After that, testing and validation of RCV based on mmWave communication will be executed with pre-defined user story, practically more focusing on data logging with the agreed data format.

The full trials phase has started in November 2021 in the 5G (mmWave) environment at KATECH's proving ground.

3.8.2 US#5.2: Tethering via vehicle using mmWave communication (Tethering)

3.8.2.1 Verification process overview

After L1-L2/L3-5G core network integration and preliminary testing was completed in October 2020, ETRI conducted a field trial on a highway test track in Yeoju, Korea, at the end of November 2020. The field trial was conducted using a mmWave OBU installed on the demo bus and network equipment including 5G core and five gNBs deployed along the trackside as shown in Figure 82.

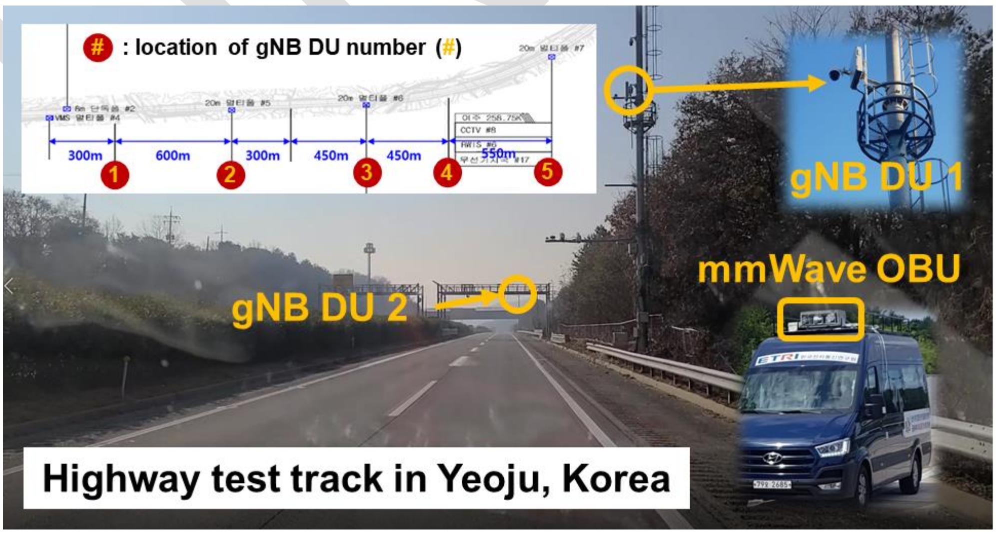

Figure 82: Field trial conducted on a highway test track in Yeoju, Korea

3.8.2.2 Main results

Table 37 gives an overview of the checklist testing status, details of which can be found in Annex 2 (Section 6.5.2:

Table 37: Verification results of the tethering user story

Group	Pass	Fail	Partly	Not tested	Completion %
Vehicle related issues	4	0	0	0	100 %
OBU related issues	5	0	0	0	100 %
Infrastructure related issues	1	0	0	0	100 %
External servers	4	0	0	0	100 %
Other end user devices	3	0	0	0	100 %
UE related issues	17	0	0	0	100 %
5G network related issues	2	0	0	0	100 %
Network related issues	2	0	0	0	100 %
Subtotal: functional issues	19	0	0	0	100 %
Logging related issues	3	0	1	2	58 %
Total	**22**	**0**	**1**	**2**	**90 %**

During the trial, it was observed that all the functionalities work as expected, which allowed us to successfully demonstrate our target user story in which broadband onboard Wi-Fi services are provided to onboard passengers.

3.8.2.3 Next steps

Since the field test was done successfully, showing the overall functionalities work properly, no further actions are required for future field trials. Nevertheless, we'll continue to work on the additional functional testing and system stabilization.

4 CONCLUSIONS

4.1 Overall outcome and synthesis of verification phase

Table 38 gives an overview of the verification results at the end of February 2022.

Table 38: Overview of the verification status for the user stories at the end of February 2022

US	TS	US Id	Verification status	Completion %
1.1.a	ES-PT	LaneMerge	Verification is completed.	100 %
1.1.b	ES-PT	Overtaking	Verification is completed.	100 %
1.5	ES-PT	CoopAutom	Verification is almost completed. The only issue remaining is related to the frequency on message sending from smart phone.	97%
3.1.a	ES-PT	HDMapsVehicle	Verification is completed.	100 %
3.1.b	ES-PT	HDMapsPublic-Transport	Verification is completed.	100 %
4.1	ES-PT	RCCrossing	Verification is completed.	100 %
5.1	ES-PT	MediaPublic-Transport	Most of the verification has been performed. Logging is being finalised and handover is being tested.	88 %
2.1.a	GR-TR	SeeWhatISee	Verification is completed	100 %
2.1.b	GR-TR	5GPlat	Integration is still ongoing. The OBUs are ready and have been tested, but still have to be integrated in the vehicles. Handover has not been able to be tested due to travel restrictions.	66 %
3.2.a	GR-TR	AssBCrossing	Verification of the basic version is completed.	100 %
			Interconnect between MECs still has to be validated	95 %
3.2.b	GR-TR	TruckRouting	Verification is completed. Logging has to be finalised.	87 %
2.2	DE	AsseRSU	Verification is completed	100 %
3.3	DE	EDM	Verification is completed.	100 %

US	TS	US Id	Verification status	Completion %
3.4	FI	EdgeProcessing	Most of the verification tests have been performed. Handover between SA networks outdoor to be tested. Logging has to be completed	94 %
4.2	FI	RedundantNE	Most of the verification tests have been performed. Handover between SA networks outdoor to be tested. Logging to be tested.	95 %
1.2	FR	AssInfrastructure	All verification tests performed except for mmWave	94 %
1.3	NL	CoCA	Verification is completed. Data will be manually uploaded to the CTS.	96 %
3.5	NL	CPM	Most of the verification tests have been performed. Handover still has to be tested.	92 %
4.3	NL	5GPositioning	Verification of remote driving has been performed.	94 %
			Tests with mm-wave network will be performed when the network is available	82 %
1.4	CN	CloudAssisted	Most of verification tests have been performed in SDIA part of CN site. Logging still under development.	95 %
2.3	CN	AssCloud	Most of the verification tests have been performed. Logging is still under development.	94 %
4.4	CN	DataOwnership	Most of the verification tests have been performed. Logging is still under development	94 %
4.5	KR	mmWave	Field tests were successful.	95 %
5.2	KR	Tethering	Field tests were successful.	90 %
Average				**95 %**

Table 39: Overview of the verification status for the contribution of the local Trial sites to the CBCs at the end of February 2022

TS	CBC	Cross-border corridor Contribution	Verification status	Completion %
FI	GR-TR	LEVIS video streaming application	Fully Integrated in the See-What I See user story	100%
FI	ES-PT	Edge discovery service	Fully integrated in the HDMapsVehicle and HDMapsPublicTransport user stories	100%
FI	ES-PT	5G Multi-SIM OBU solution	Verification tests have been performed locally. Connectivity to the ES-PT networks still has to be tested	93 %
FR	ES-PT	5G connected car	Verification tests have been performed locally. Connectivity to the ES-PT networks still has to be tested	74 %
FR	ES-PT	5G Multi-SIM OBU solution	Verification tests have been performed locally. Connectivity to the ES-PT networks still has to be tested	84 %
NL	ES-PT	MCS application	Application verification performed. Connection to the PT network, handover and roaming will be tested in March 2022.	76 %
DE	ES-PT	Extended sensors solution incl. 5G connected car, Multi-SIM OBU, PC5 RSU and MEC	Verification is almost complete, except for handover related issues in the ES-PT network.	94 %

Figure 83 gives an overview of the completion of verification for the different user stories (including the contribution of the local trial sites to the CBCs). For only two user stories the completion is less than 80%: for the 5G platooning in the GR-TR CBC and for the 5G connected vehicle contribution from the French trial site to the ES-PT CBC.

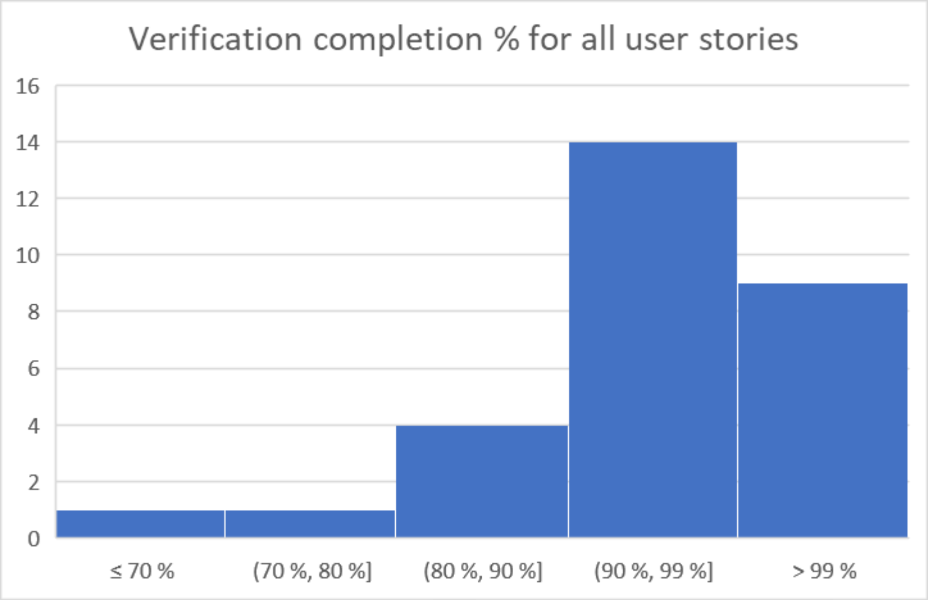

Figure 83: Verification completion percentage for all user stories

4.2 Next steps

Most of the user stories have proceeded to the trial phase. Some verification tests still have to be completed. Especially for the GR-TR CBC, cross-border handover has still to be tested, and for the contributions of the local trial sites to the CBCs, missing verification tests are related to tests needed in the CBC infrastructure, which will be performed directly prior to the actual trials, when the teams of the local trial sites are travelling to the CBC. These delays have been mainly caused due to restrictions in travelling and border crossing due to COVID-19. For some user stories, infrastructure development, e.g. related to mm-Wave, was delayed, and tests will be performed in March 2022.

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5 ANNEX 1: SEQUENCE DIAGRAMS

5.1 UCC#1: Advanced Driving

5.1.1 US#1.1.a: Complex Manoeuvres in Cross-Border Settings: Lane Merge for Automated Vehicles (ES-PT)

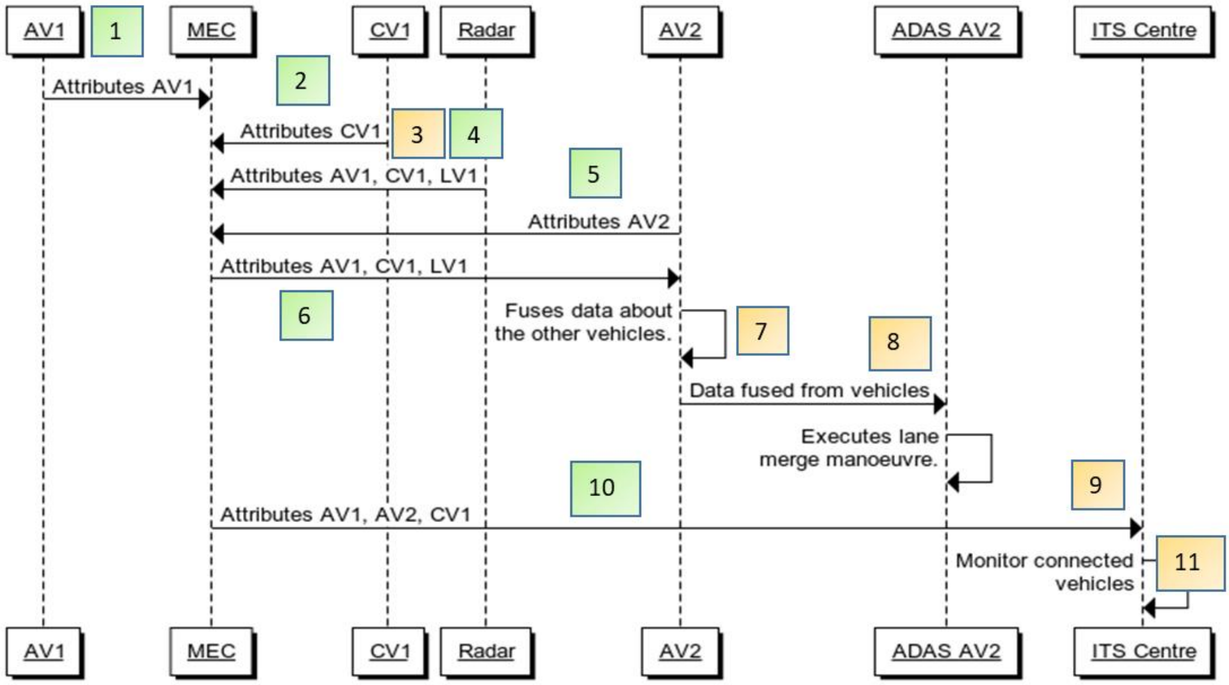

Figure 84: Sequence diagram of the lane merging user story

5.1.2 US#1.1.b: Complex Manoeuvres in Cross-Border Settings: Overtaking (ES-PT)

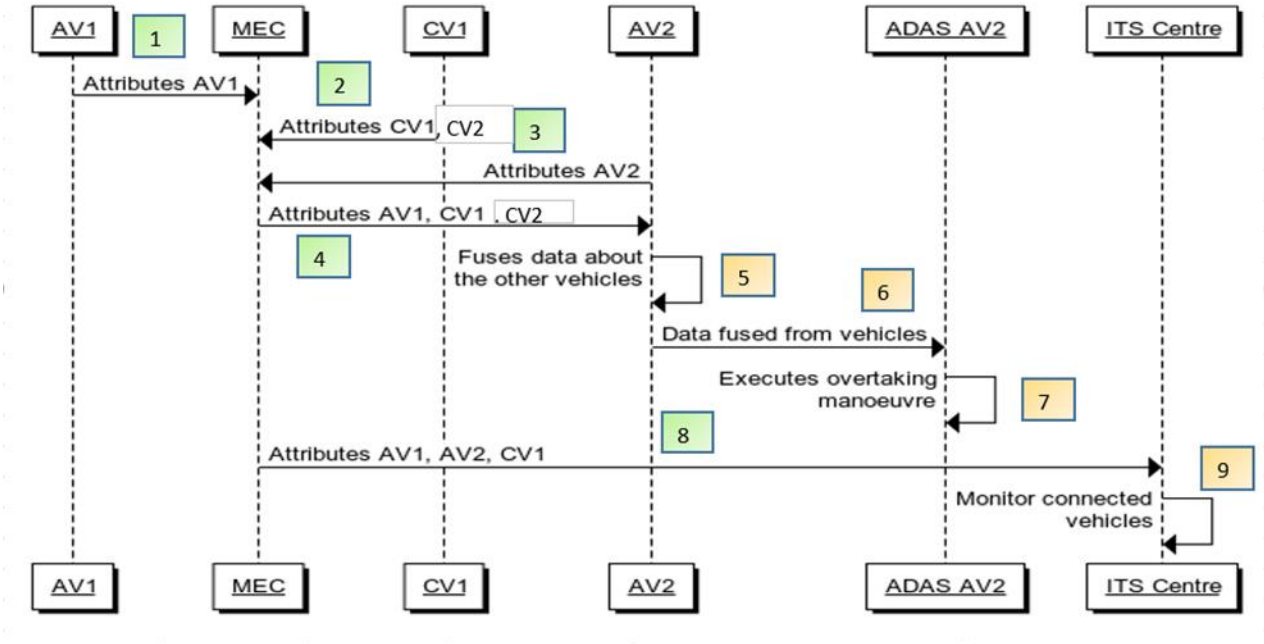

Figure 85: Sequence diagram of the automated overtaking user story of ES-PT

5.1.3 US#1.2: Infrastructure-Assisted Advanced Driving (FR)

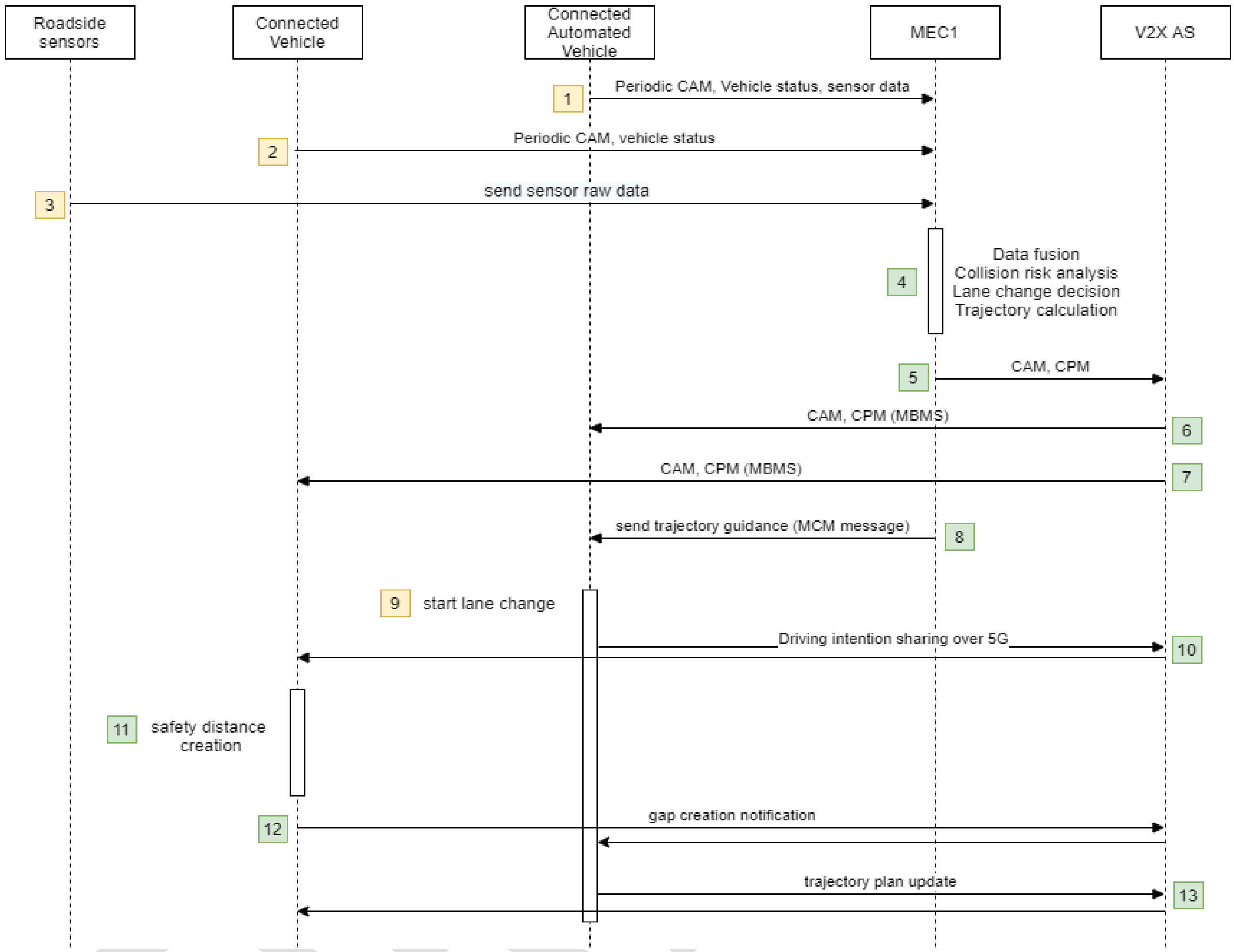

Figure 86: Infrastructure assisted advanced driving sequence diagram (1/2)

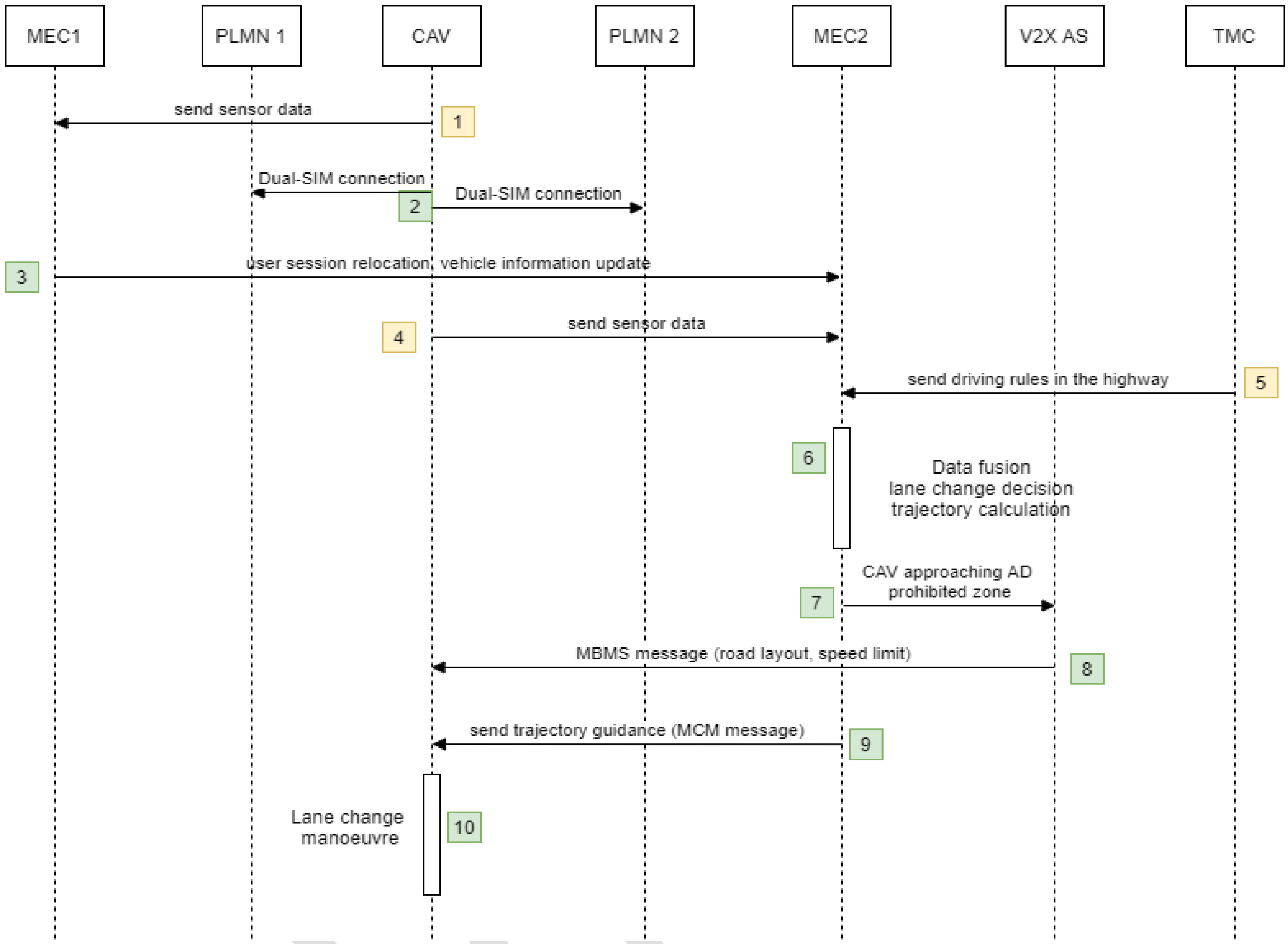

Figure 87: Infrastructure assisted advanced driving sequence diagram (2/2)

5.1.4 US#1.3: Cooperative Collision Avoidance (NL)

The use case is described in D2.1 [1]. The objective of the use case is High bandwidth, low latency data exchange for safety-critical application of Cooperative Collision Avoidance.

The service uses the MCS (Manoeuvre Coordinating Service) concept, which is currently still under standardisation. The concept is still being defined, and there are several competing proposals. The trial site will use the MCM (Manoeuvre Coordination Message), as has been defined by the TRANSAID project, which allows both V2V and V2I support.

In the V2V scenario, vehicles communicate on a peer-to-peer basis with each other and exchange the planned (collision-free) trajectory, and potentially the desired trajectory. The sequence diagram for the V2V data exchange is shown in Figure 88.

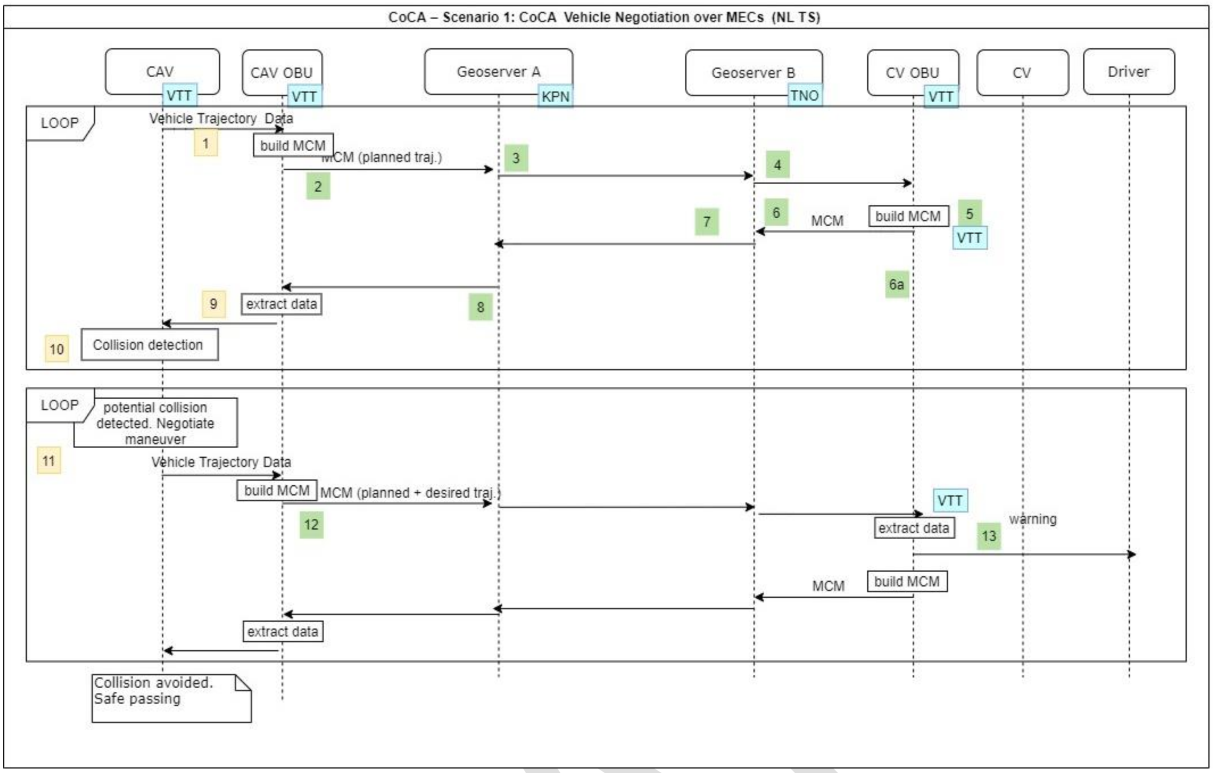

Figure 88: Sequence diagram for the CoCA V2V scenario

In the V2I scenario, an application at the MEC provides advices to the vehicles which are on a collision course. The sequence diagram for the V2V data exchange is shown in Figure 89.

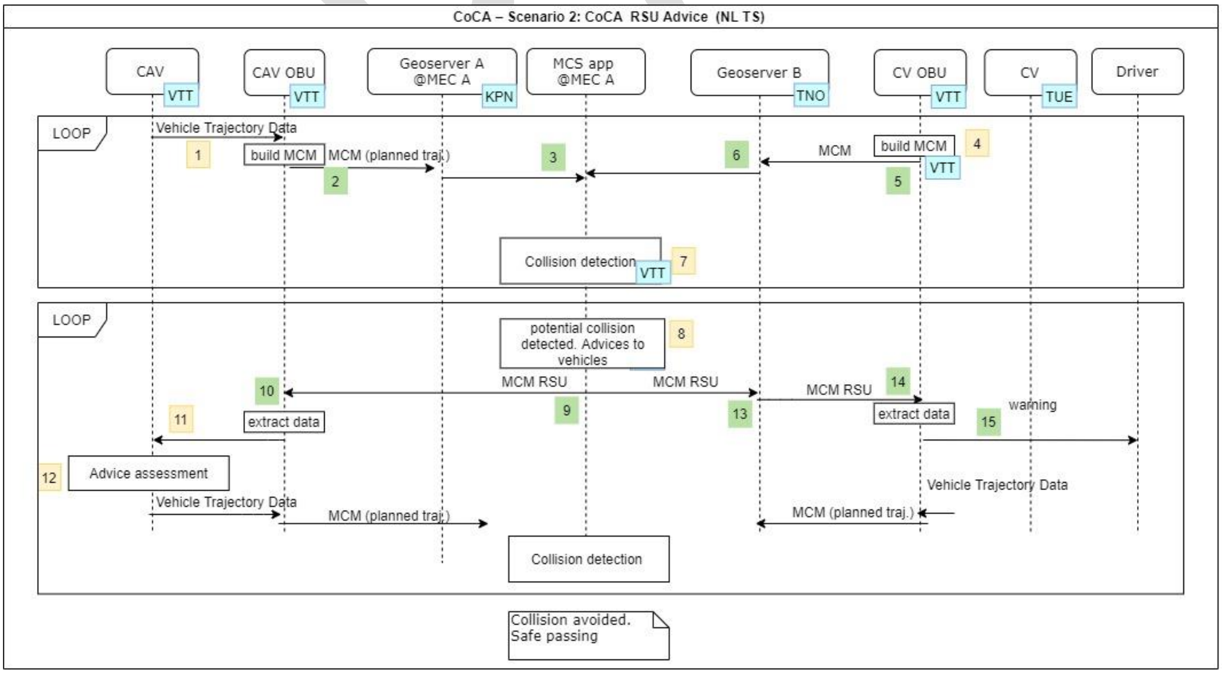

Figure 89: Sequence diagram of Cooperative Collision Avoidance user story

5.1.5 US#1.4: Cloud-Assisted Advanced Driving (CN)

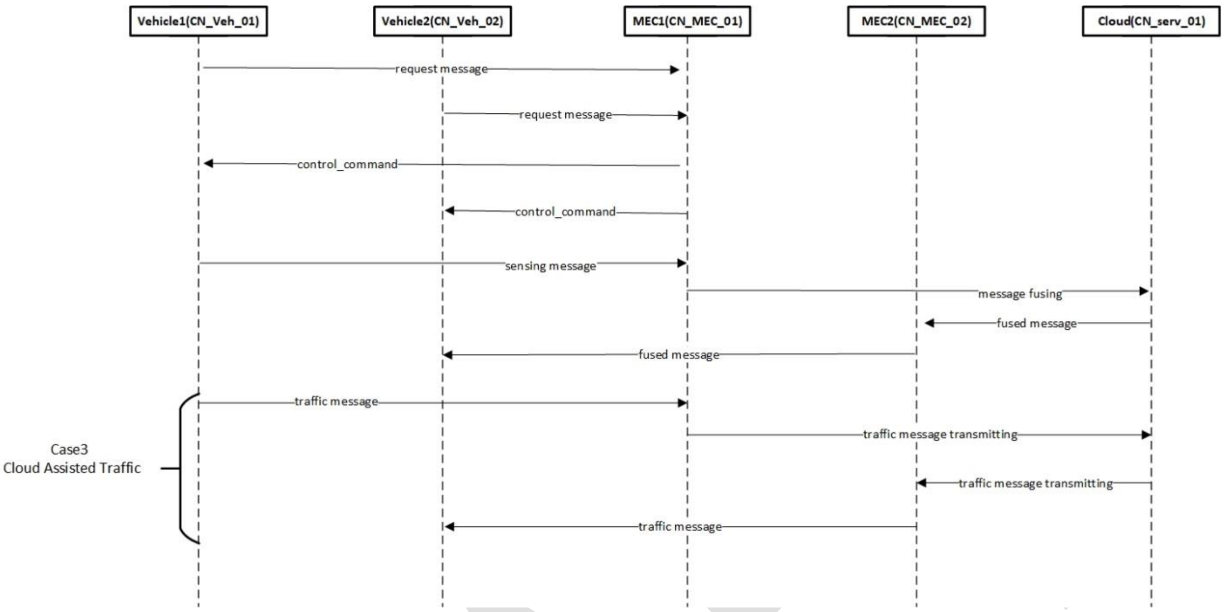

Figure 90: Sequence diagram of Cloud-assisted advanced driving

5.1.6 US#1.5: Automated Shuttle Driving Across Borders: Cooperative Automated System (ES-PT)

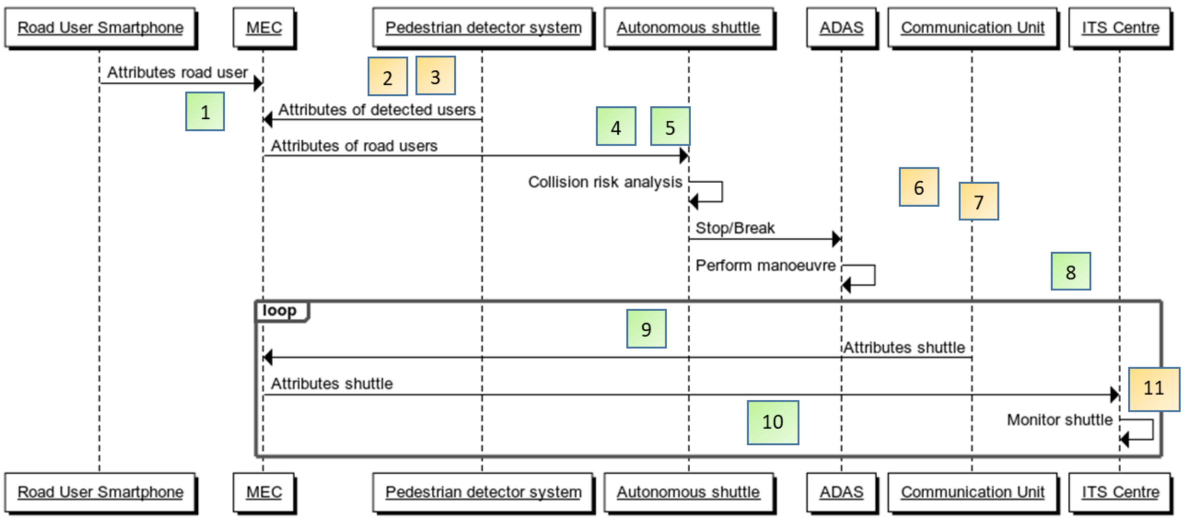

Figure 91: Sequence diagram of the automated shuttle user story

5.2 UCC#2: Vehicles Platooning

5.2.1 US#2.1.a: Platooning with "See What I See" Functionality in Cross-Border Settings (GR-TR)

During platooning, leader vehicle will stream 4K video from its front camera to follower truck through 5G network. Platoon manoeuvres will be join, maintain, split, merge and dissolve.
According to scenario, when platoon reaches to the initial gate, platoon will be dissolved by the leader truck driver. After that, follower truck will pass through first gate manually. Later, driver initiate autonomous truck routing application via HMI in vehicle. After this point, Tübitak Cloud will gather sensor and CCTV information that are located in area and ego vehicle position, speed, and acceleration information through 5G network. Afterward, cloud will fuse all information and provide safe waypoints to ego vehicle, again through 5G network and ego vehicle will follow these safe waypoints autonomously without any human intervention (Note: a safety driver will always be inside of the vehicle.). When vehicle reached the second gate, it will stop, and driver will deliver his/her passport and cargo related information to customs officers. Thereafter, vehicle will be autonomously routed to the X-ray building, via cloud. In X-ray building, scanned images will be delivered to Tübitak Cloud via fibre cables. Cloud will analysis these images with its AI and ML power and inform customs officers. After analysis is done and no issue found, vehicle will move autonomously to the exit of the X-ray building then driver will drive vehicle autonomously until the crossing border point exit.

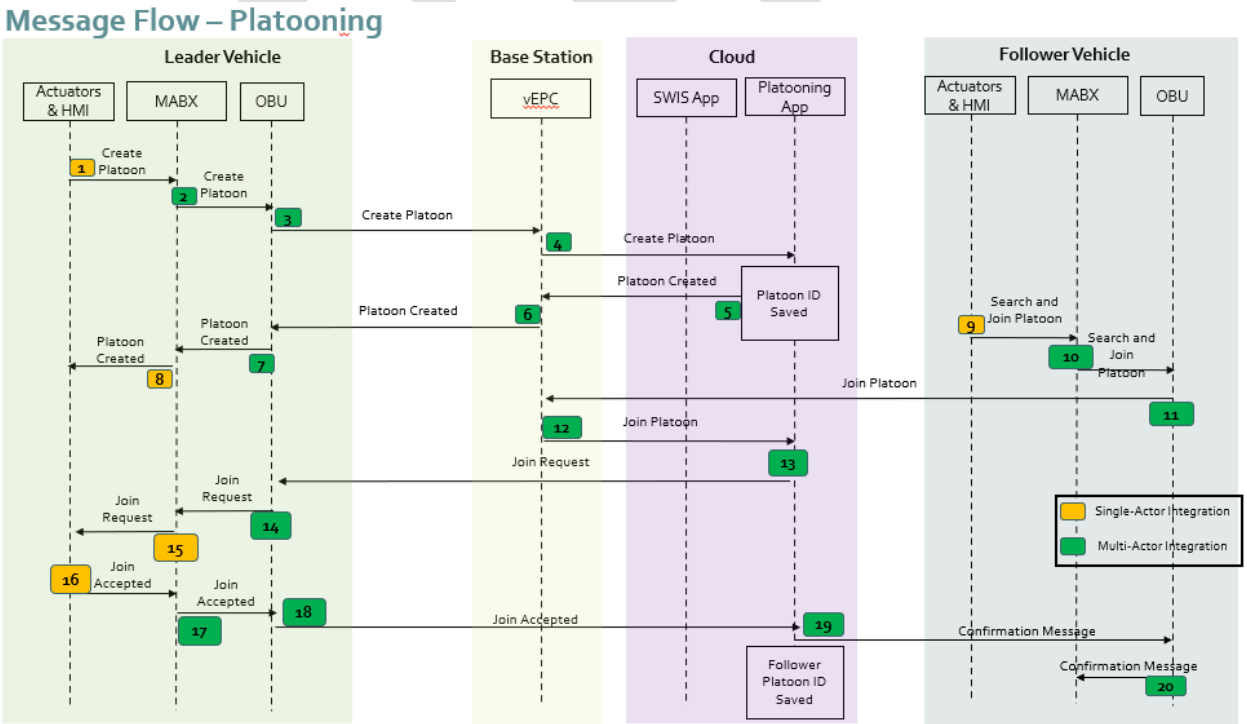

Figure 92: Sequence diagram of the Platooning with "see what I see" functionality user story (1/2)

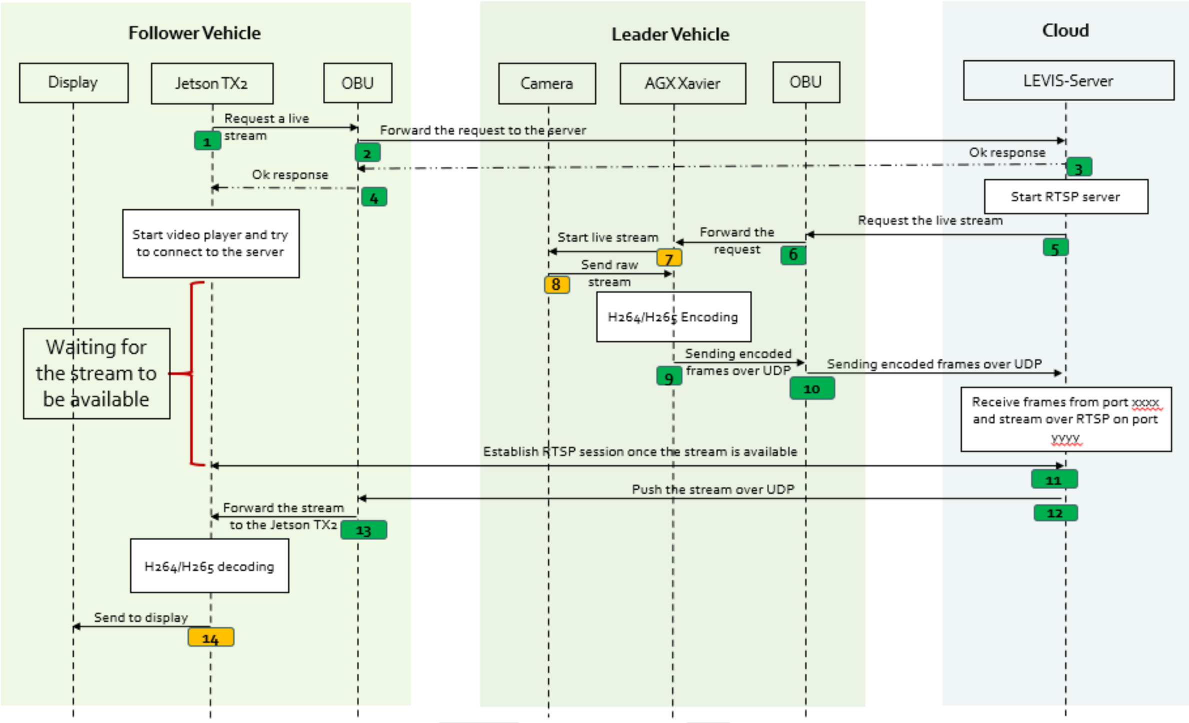

Figure 93: Sequence diagram of the Platooning with “see what I see” functionality user story (2/2)

5.2.2 US#2.1.b: Platooning through 5G connectivity

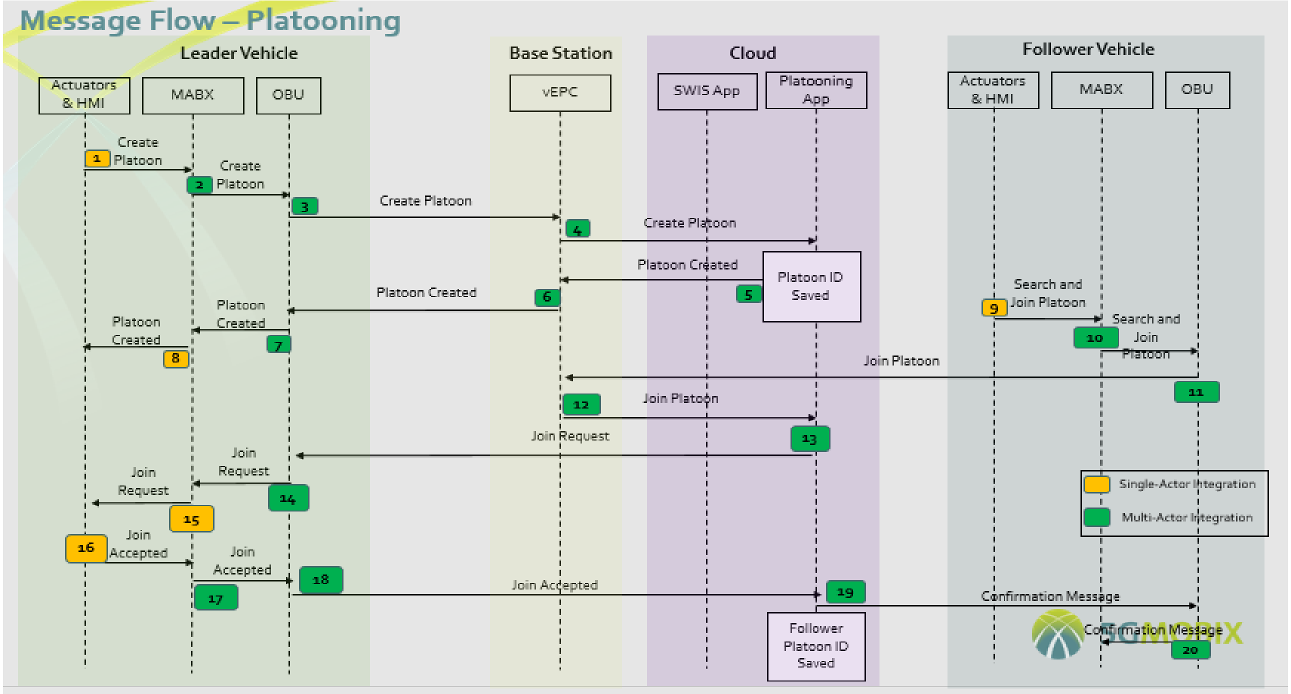

Figure 94: Sequence diagram of the 5G platooning user story

5.2.3 US#2.2: eRSU-Assisted Platooning (DE)

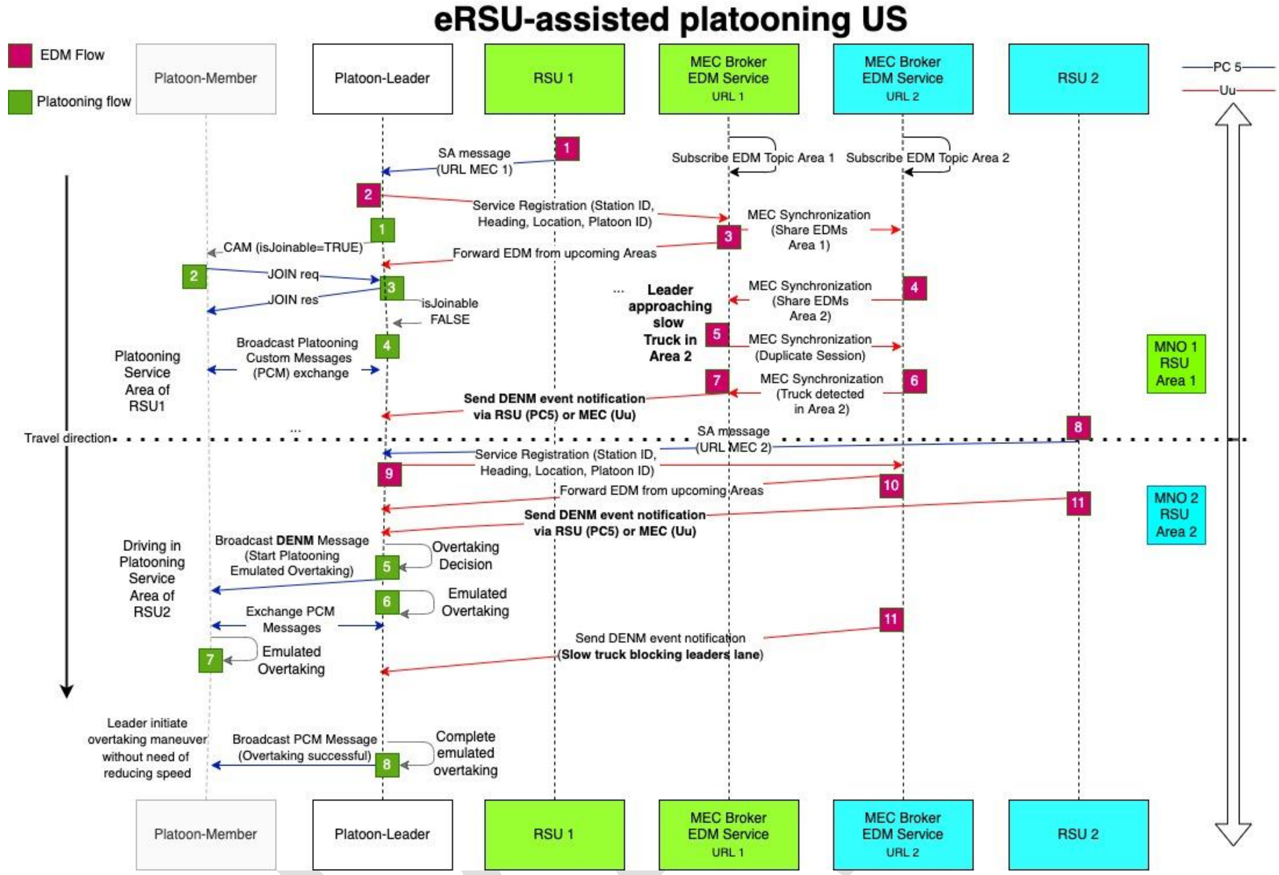

Figure 95: eRSU-assisted platooning sequence diagram

5.2.4 US#2.3: Cloud-Assisted Platooning (CN)

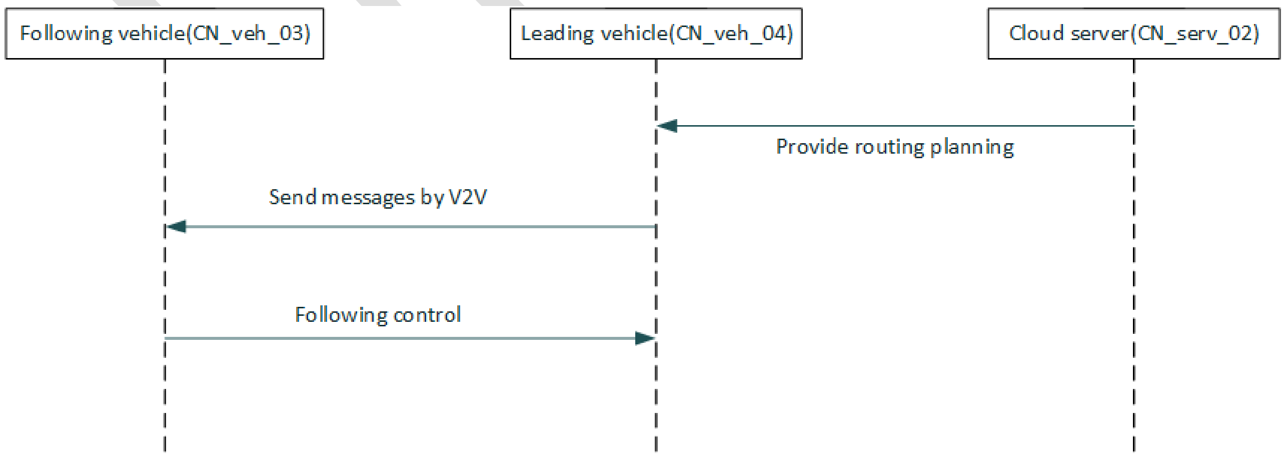

Figure 96: Sequence diagram of user story

5.3 UCC#3: Extended Sensors

5.3.1 US#3.1.a: Complex Manoeuvres in Cross-Border Settings: HD Maps (ES-PT) and US#3.1.b: Public Transport: HD Maps

Both HD maps scenarios considered under the Extended Sensors category are very similar, and follow this summarized sequence:

1. Firstly, the ITS Centre notify the first vehicle (CAV or CV) of the existence of a road event.
2. Then, the vehicle is controlled manually along the road event, and at the same time, the vehicle records the sensor data outputs.
3. All the sensor data is packaged into a log file, and it is uploaded to the ITS Centre.
4. The ITS Centre processes the log file, fuses the sensor data and generates a new map of the area.
5. Lastly, the ITS Centre send map updates to all the autonomous vehicles near the road event.
6. Once those autonomous vehicles have updated its map, they are able to drive autonomously through the road event.

However, both scenarios have meaningful differences:

- US#3.1.a (HDMapsVehicle): the main vehicle in this scenario is an autonomous vehicle. When it receives the road event notification, the vehicle checks if this event is already registered in its internal map. If the event already exists, it is already registered so the vehicle is able to drive autonomously along the event. Otherwise, it has to ask the driver to take the control for recording the new path.
- US#3.1.b (HDMapsPublicTransport): the main vehicle in this scenario is a connected manual bus. When it receives the road event notification, it does not have maps unit for checking the existence of the event, so the bus always records the road event.

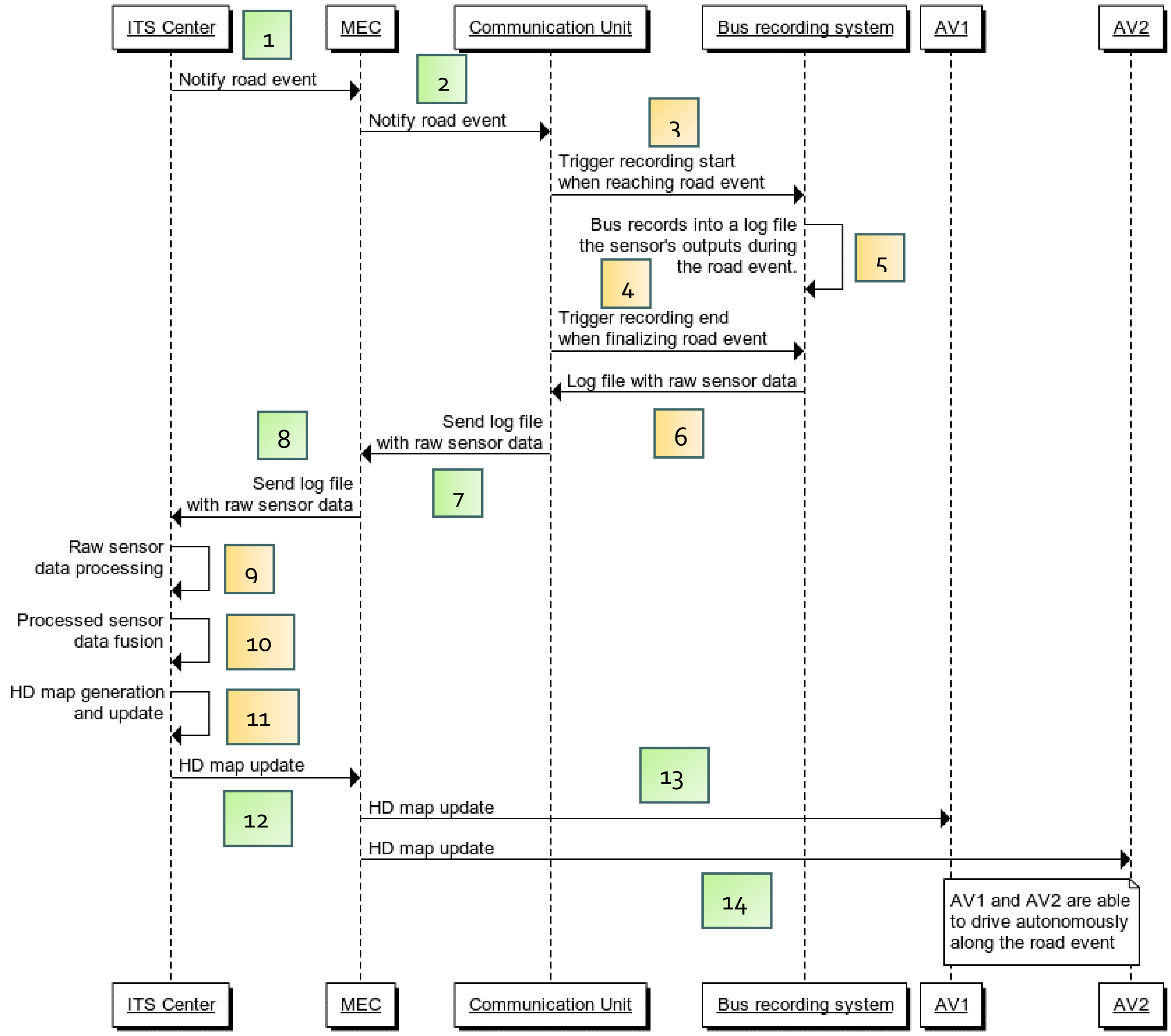

Figure 97: Sequence diagram of the HD maps user story

5.3.2 US3.2.a: Extended Sensors for Assisted Border-Crossing (GR-TR)

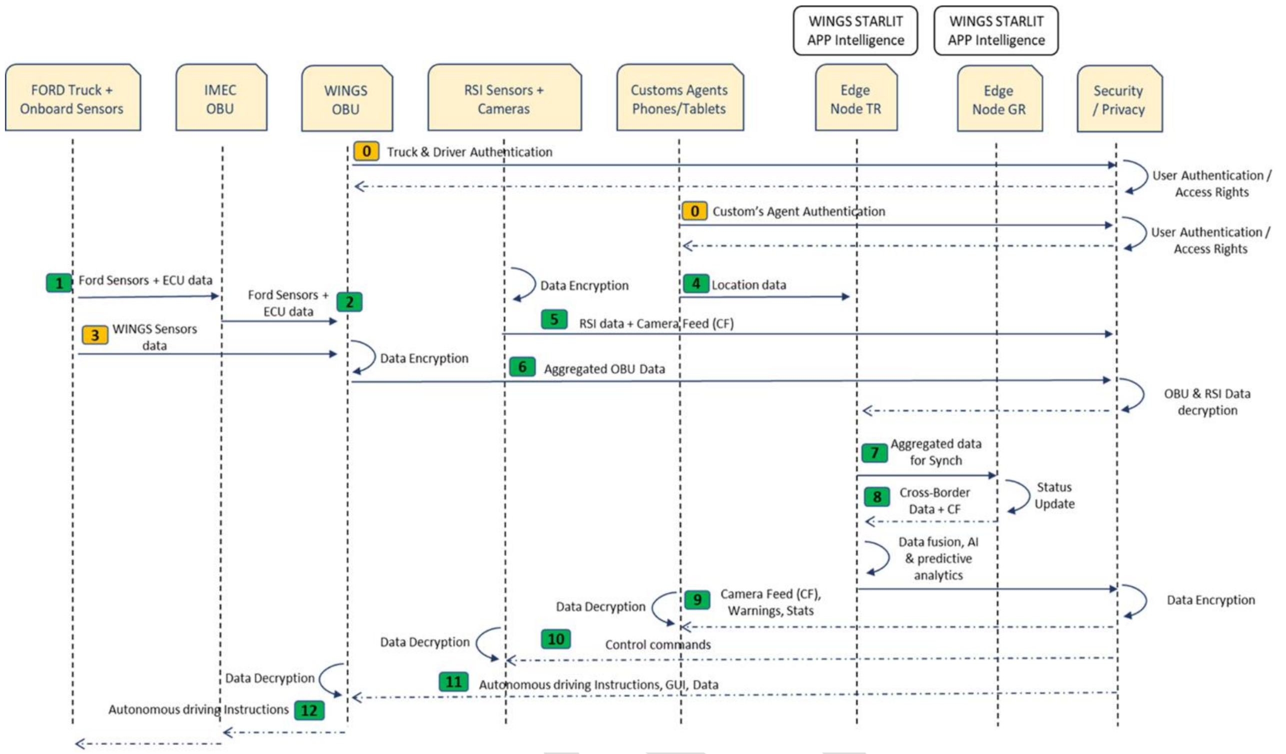

Figure 98: Sequence diagram of the Extended Sensors for assisted border crossing user story

PL	DE	Source	Range	Bit Size	Message Type	States	Integer Definition	Comment	start byte	type	factor	unit
TRUCK ROUTING	TruckRoutingStatus	Ego Truck & Cloud	0-3	8		0	No request		0	uint8	1	
						1	Send Truck Routing Request					
						2	Send Routing "Accepted" Acknowledge					
						3	Send Routing "Rejected" Acknowledge					
	Emergency Stop	WINGS OBU	0-1	8		0	Emergency Stop is "FALSE"	Do not stop vehicle.	1	uint8	1	
						1	Emergency Stop is "TRUE"	Stop vehicle.				
	Waypoints X	Cloud		16x250				250 Waypoints that contain X coordinates	2	int16		
	Waypoints Y	Cloud		16x250				250 Waypoints that contain Y coordinates	502	int16		
	Waypoints Vel	Cloud		8x250				250 Waypoints that contain vehicle speed	1002	uint8		
	RPM Value	Ego Truck		16				RPM value from CAN bus	1252	uint16	0.125	
	TimeHour	Ego Truck		8				From RTK	1254	uint8	1	hr
	TimeMinute	Ego Truck		8				From RTK	1255	uint8	1	min
	TimeSecond	Ego Truck		8				From RTK	1256	uint8	1	s
	TimeHSecond	Ego Truck		8				From RTK	1257	uint8	0.01	s
	Vehicle Speed	Ego Truck		16				Vehicle speed	1258	int16	0.01	km/h
	Latitude	Ego Truck		32				From RTK	1260	int32	1,00E-07	degree
	Longitude	Ego Truck		32				From RTK	1264	int32	1,00E-07	degree
	Altitude	Ego Truck		32				From RTK	1268	int32	0.001	degree
	Heading	Ego Truck		16				From RTK	1272	uint16	0.01	degree
	Reserved	Ego Truck		16				Reserved for future usage	1274	uint8	1	

Figure 99: Agreed message format from the FORD truck to the OBUs (IMEC and WINGS)

5.3.3 US#3.2.b: Truck Routing in Customs Area (GR-TR)

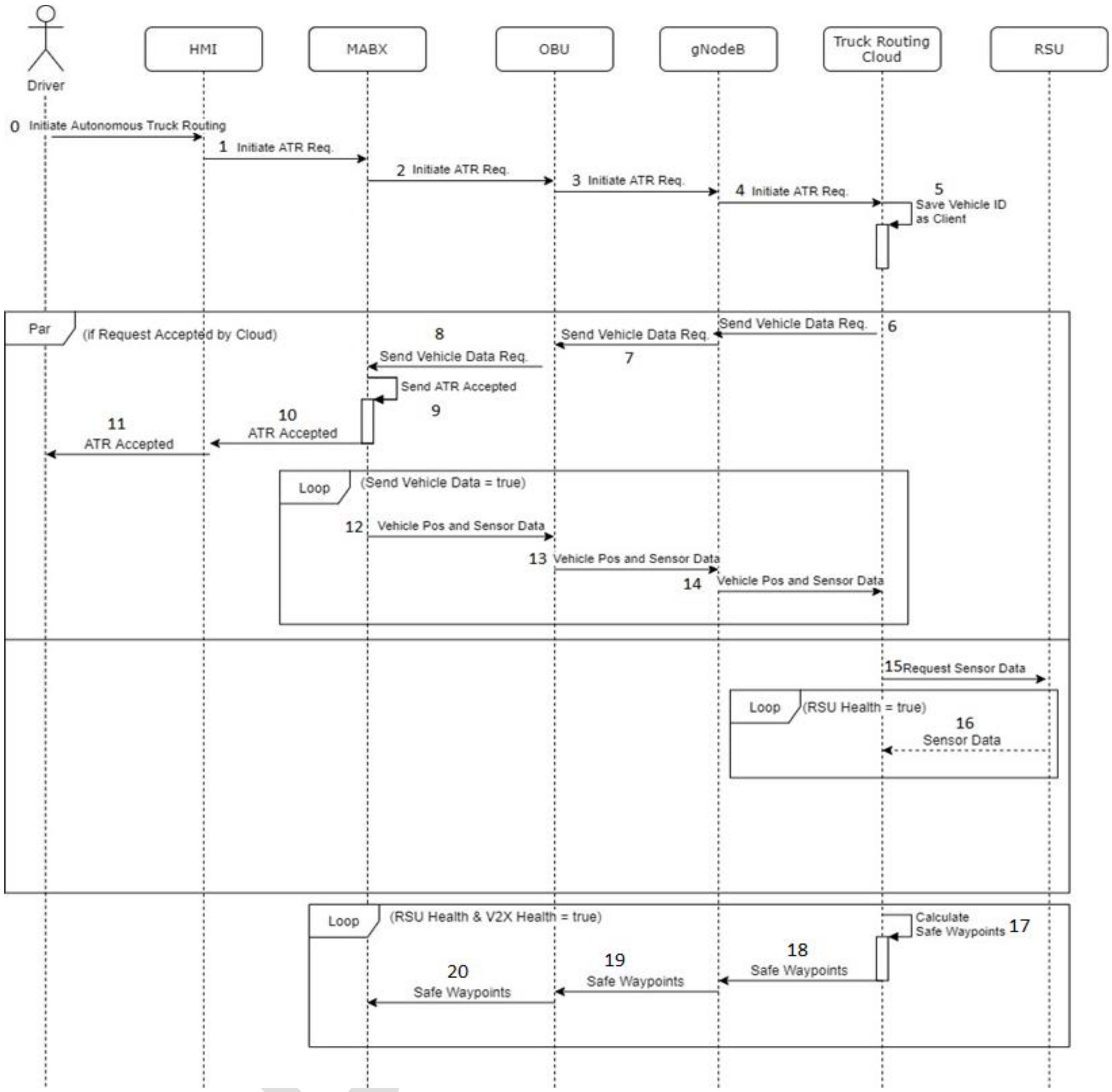

Figure 100: Sequence diagram for the Truck Routing in Customs Area user story

5.3.4 US#3.3: EDM-Enabled Extended Sensors with Surround View Generation (DE)

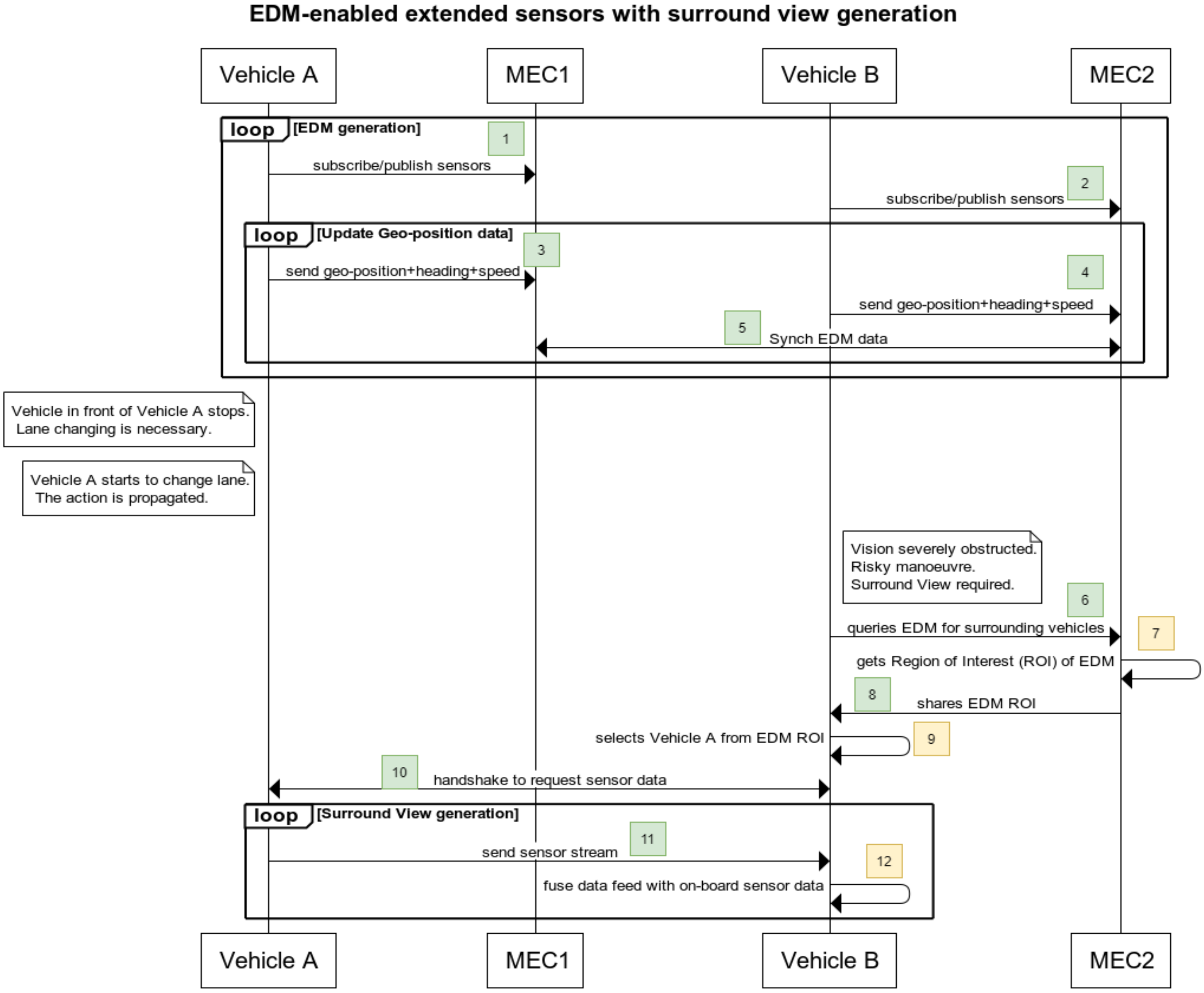

Figure 101: Sequence diagram for EDM-enabled extended sensors with surround view generation user story

5.3.5 US#3.4: Extended Sensors with Redundant Edge Processing (FI)

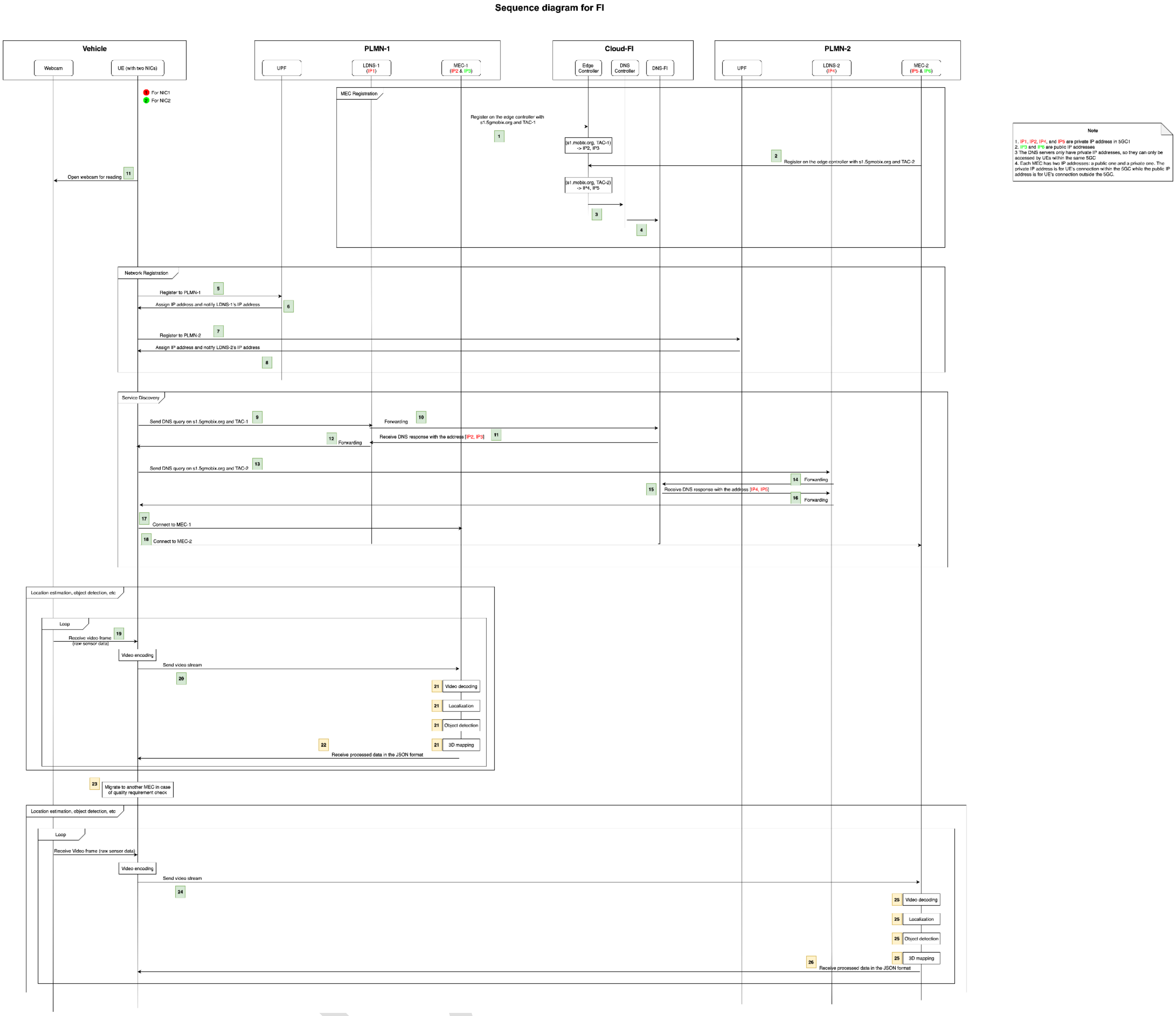

Figure 102: Extended sensors with redundant edge processing sequence diagram

5.3.6 US#3.5: Extended Sensors with CPM Messages (NL)

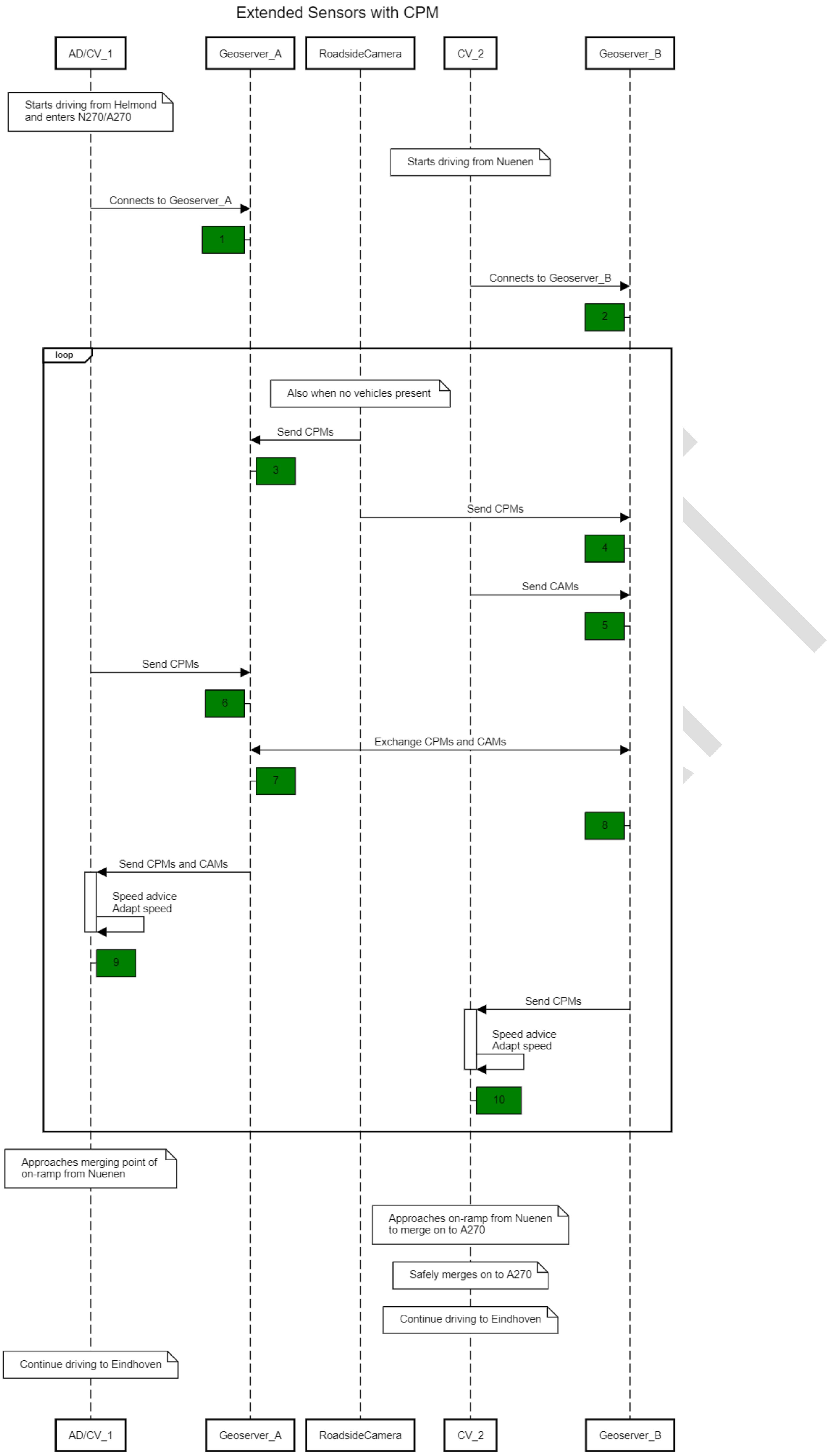

Figure 103: Sequence diagram - Extended sensors with CPM messages

5.4 UCC#4: Remote Driving

5.4.1 US#4.1: Automated Shuttle Remote Driving across Borders (ES-PT)

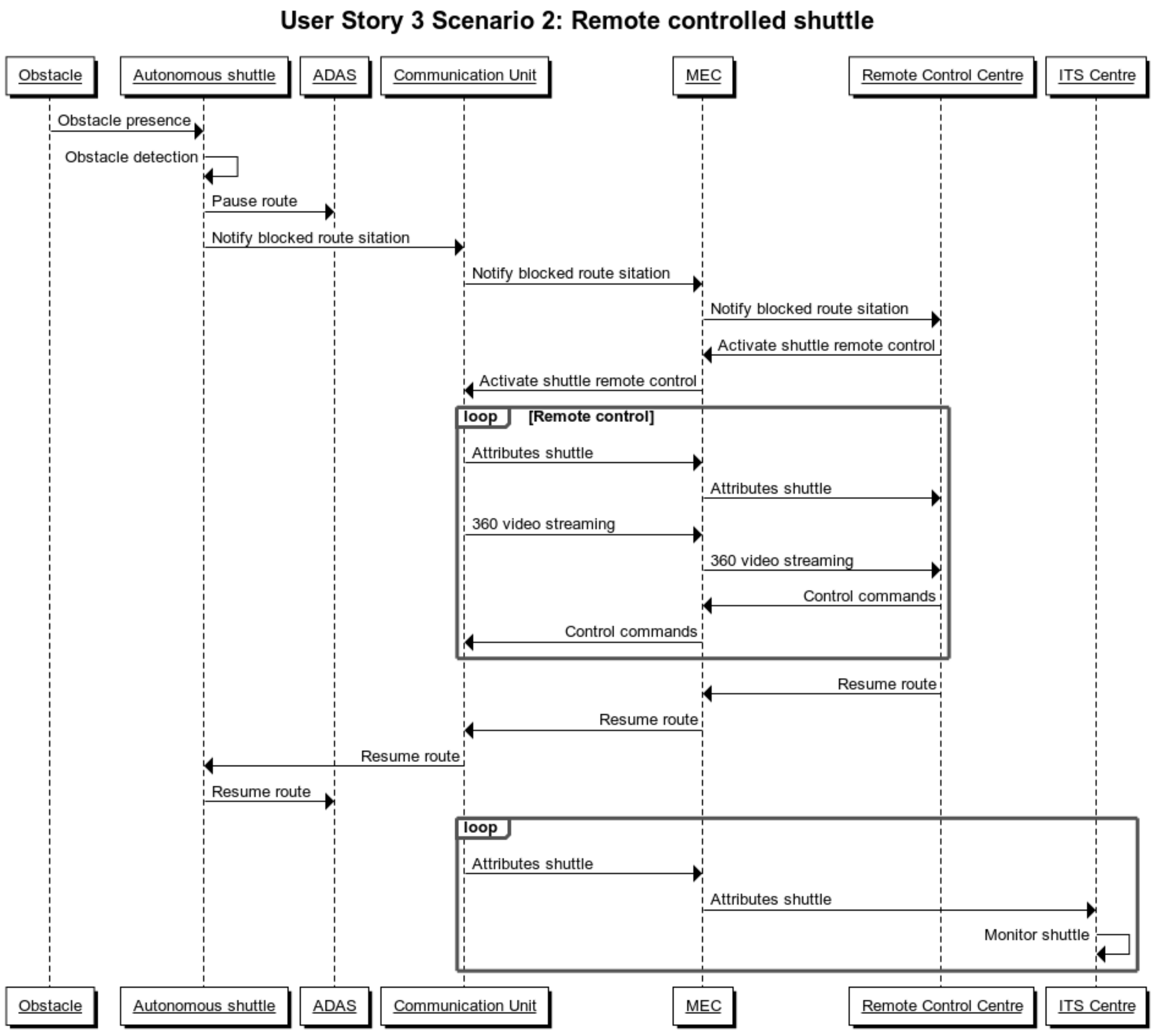

Figure 104: Sequence diagram of the Remote Driving scenario of ES-PT US3

5.4.2 US#4.2: Remote Driving in a Redundant Network Environment (FI)

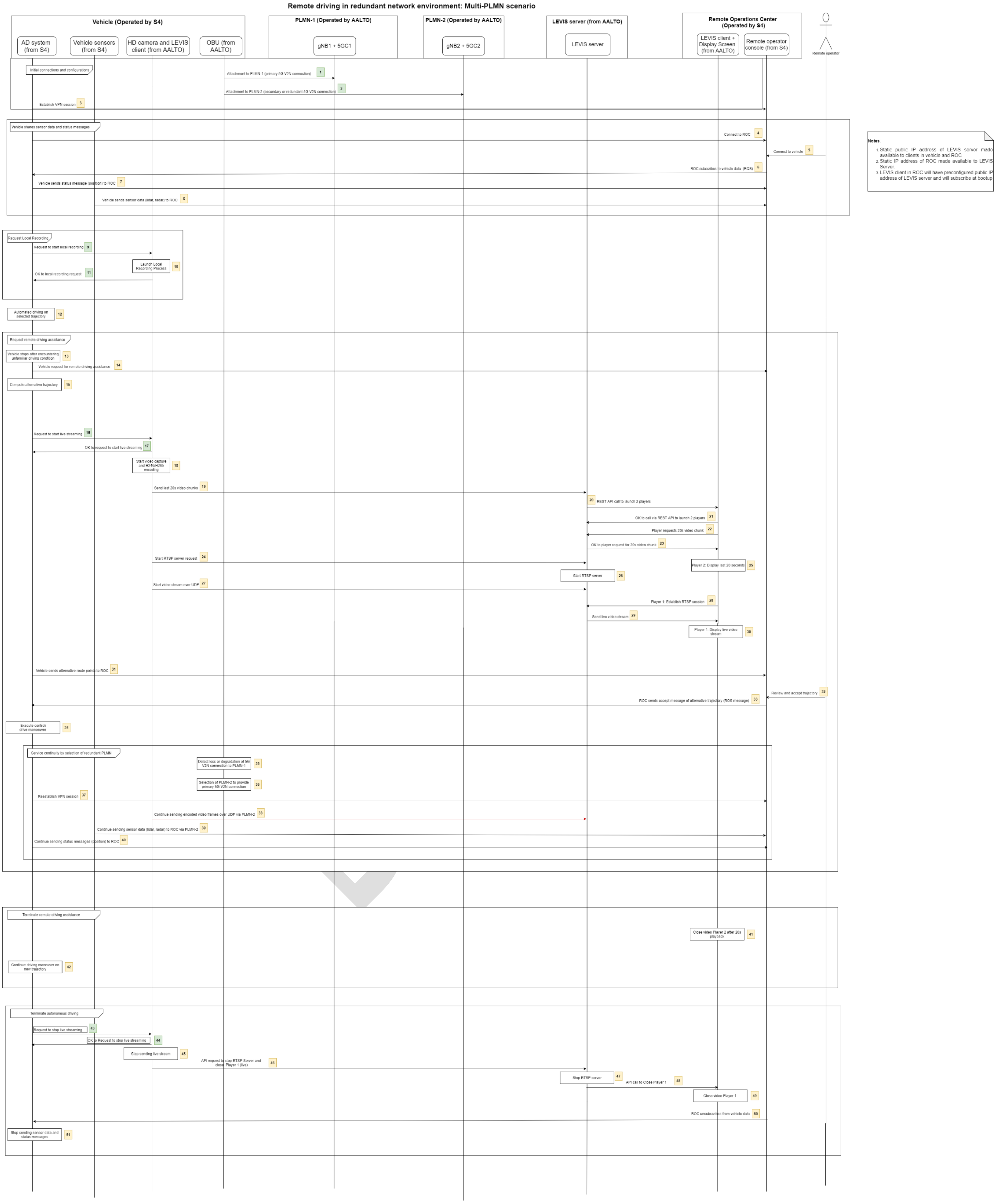

Figure 105: Sequence diagram for Remote driving in a redundant network environment

5.4.3 US#4.3: Remote Driving using 5G Positioning (NL)

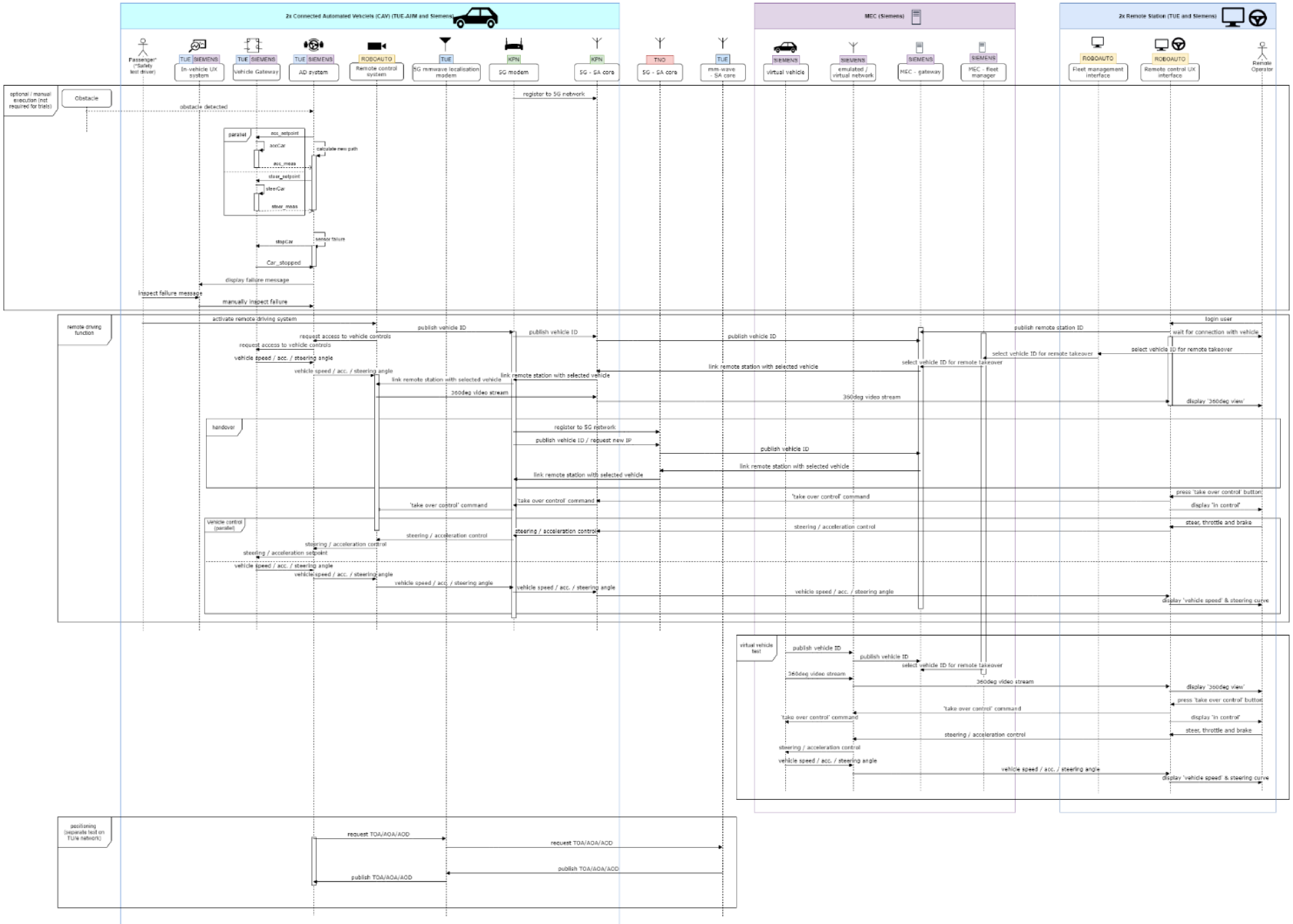

Figure 106: Remote driving using 5G positioning sequence diagram

5.4.4 US#4.4: Remote Driving with Data Ownership Focus (CN)

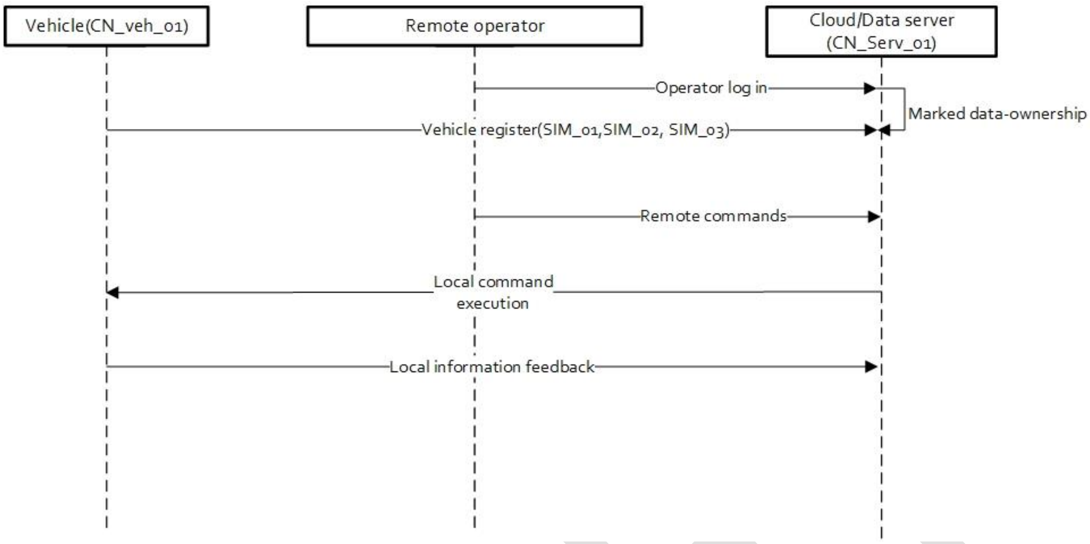

Figure 107: Sequence diagram of Remote driving with data ownership focus

5.4.5 US#4.5: Remote Driving using mmWAVE Communication (KR)

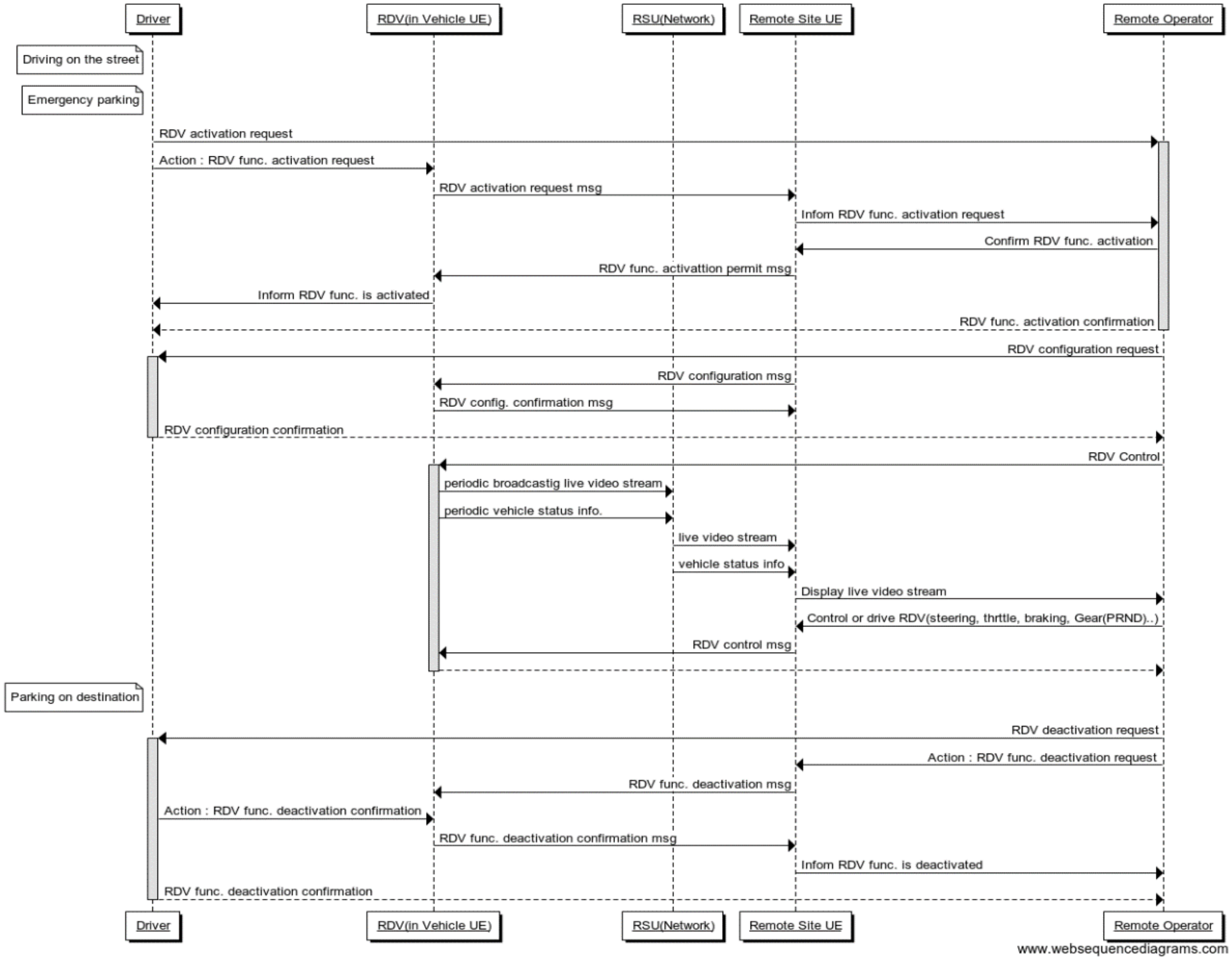

Figure 108: Sequence diagram of Remote driving using mmWAVE

5.5 UCC#5: Vehicle QoS Support

5.5.1 US#5.1: Public Transport with HD Media Services and Video Surveillance (ES-PT)

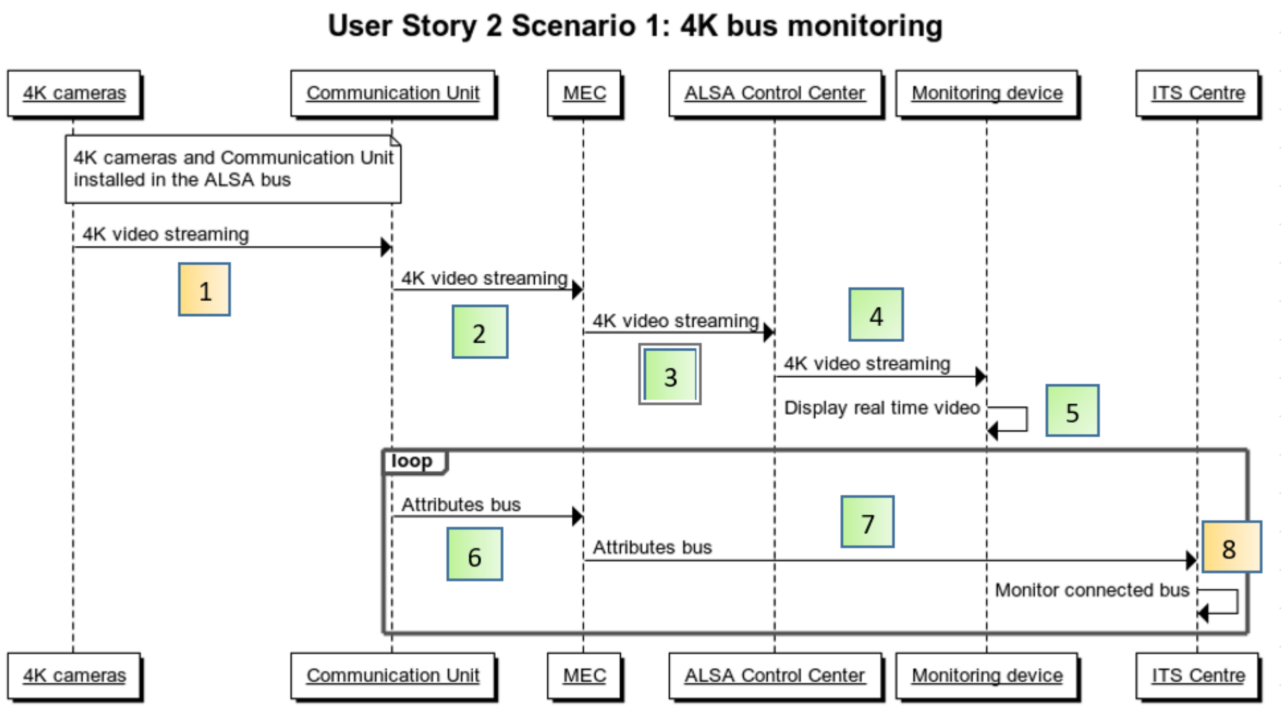

Figure 109: Sequence diagram of the 4k bus monitoring scenario of ES-PT US2

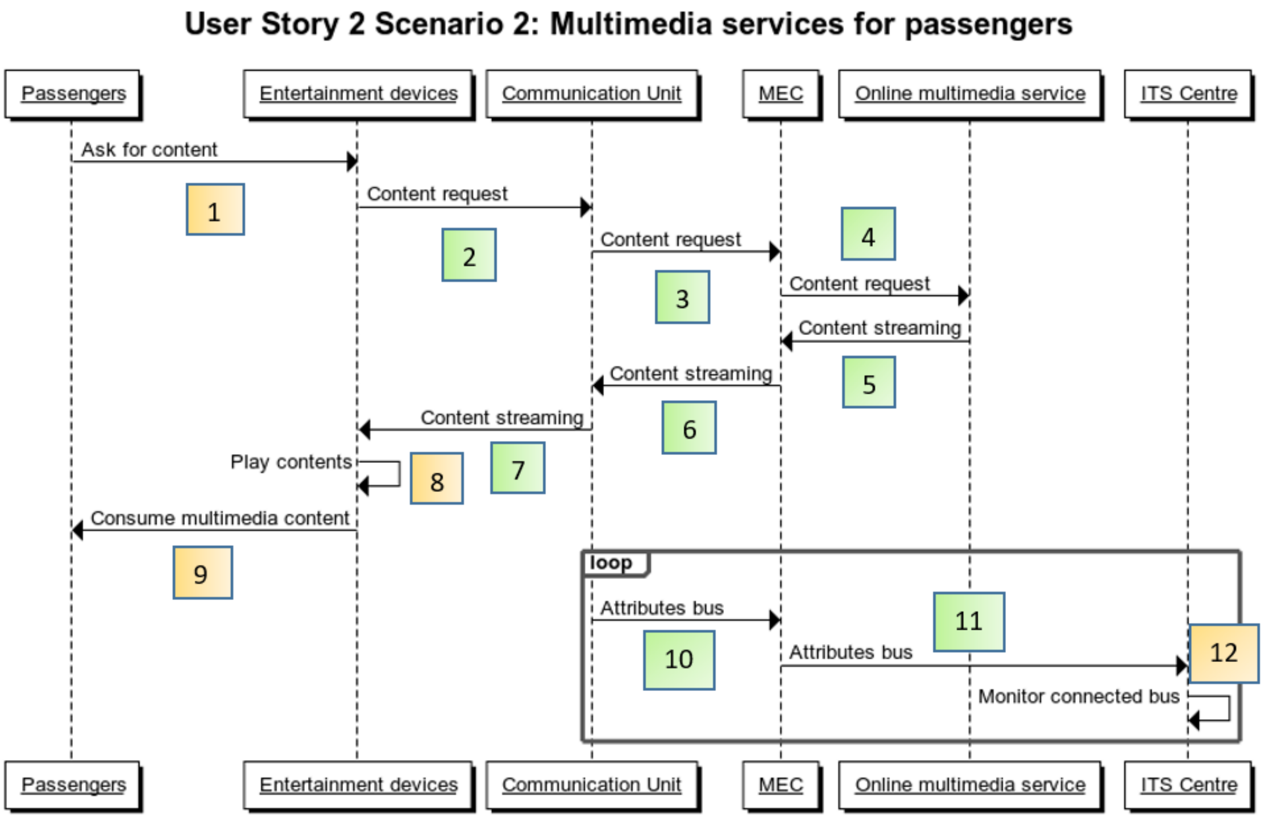

Figure 110: Sequence diagram of the multimedia services for passengers scenario of ES-PT US2

5.5.2 US#5.2: Tethering via Vehicle using mmWave Communication (KR)

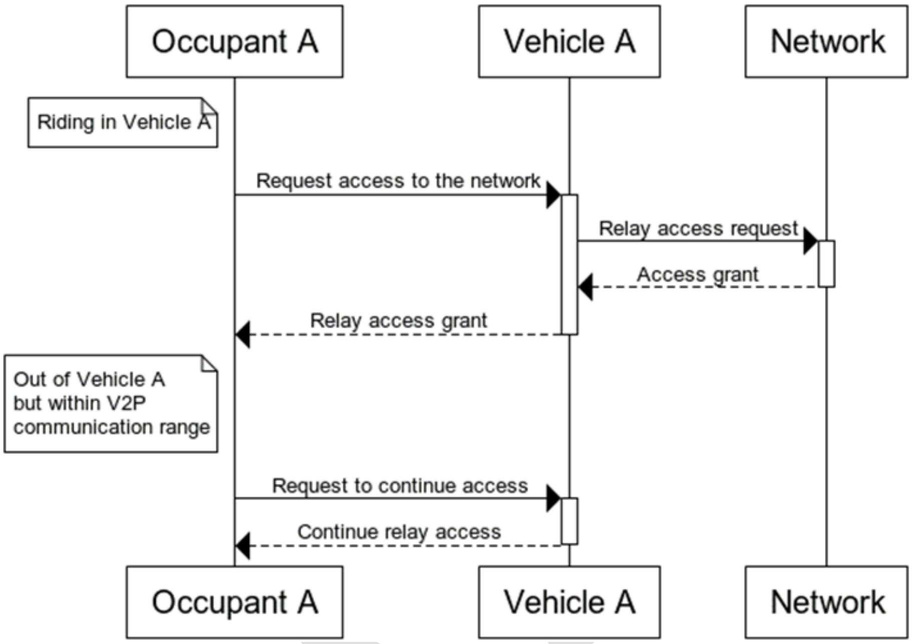

Figure 111: Sequence diagram for tethering via vehicle using mmWave communication

5.6 Contribution of the local trial sites to the CBCs

5.6.1 Contribution of TS FR to CBC ES-PT: 5G Connected Vehicle

The verification steps include those described in the sequence diagram of Section 5.1.1. The FR TS 5G connected vehicle will test interoperability via messages exchange (CAM, CPM) with "local vehicles" used in the ES-PT user story lane 1.1.a.

5.6.2 Contribution of TS NL to CBC ES-PT: MCS Application

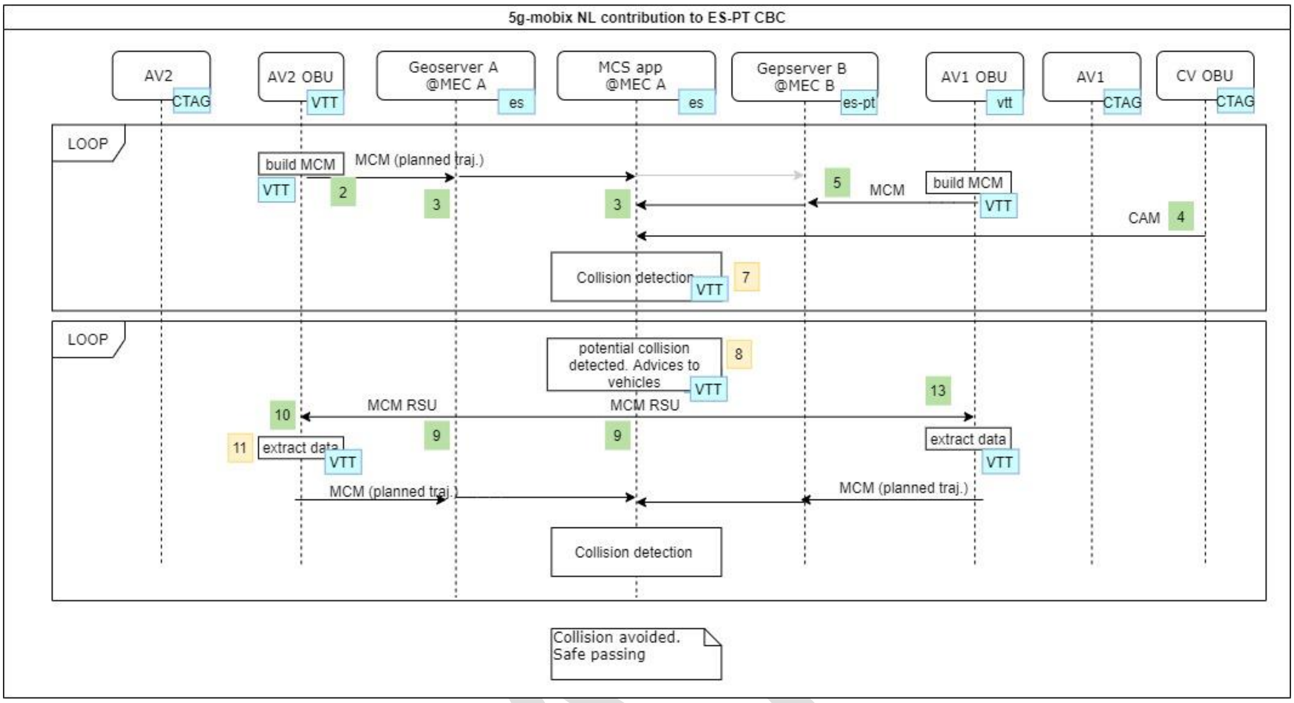

Figure 112: Sequence diagram of the MCS application

5.6.3 Contribution of TS FI to CBC GR-TR: LEVIS Video Streaming Application

The verification steps include those involving the LEVIS server and client in the sequence diagram of the user story (Figure 105). Please refer to Sections 3.4.3 and 5.4.2 for further details.

5.6.4 Contribution of TS DE to CBC ES-PT: Extended Sensors solution including 5G connected car, Multi SIM OBU, PC5 RSUs and MEC instances

Verification of the DE trial site user story and components at the ES-PT cross-border corridor will follow the same sequence diagram presented in Section 5.3.4. Additional complexities that may emerge would mainly relate to the practical considerations of initial site access and network setup.

5.6.5 Contribution of TS FI to CBC ES-PT: Edge Discovery Service

The verification steps include those described in the sequence diagram of Section 5.3.5, except that the service discovery developed by AALTO assists to discover the ITS centers in Spain and Portugal instead of the MEC servers in the multi-PLMN testbed in Finland; and that the HD map application also developed by AALTO is not deployed in the CBC.

5.6.6 Contribution of TS FI to CBC ES-PT: Multi SIM OBU Solution

This is an agnostic test case which is about a connectivity test. The FI multi-SIM OBU was part of pre-trials in Finland (February 11-12, 2021) and has been verified then. This is not part of a specific user story with multiple verification steps. However, the sequence diagram of Figure 105 in Section 5.4.2 illustrates the basic connectivity verification steps (steps 1 and 2 connecting the multi-SIM OBU to the CBC networks; instead to the multi-PLMN testbed in Finland).

5.6.7 Contribution of TS FR to CBC ES-PT: Multi SIM OBU Solution

This is an agnostic test case related to FR TS proposed solution for providing seamless connectivity at the cross border. The FR multi-SIM OBU will be pre-tested in the FR TS in the coming weeks. This is not part of a specific user story with multiple verification steps. However, the sequence diagram of Figure 104 in Section 5.4.1 illustrates the basic connectivity verification steps (steps 1 and 2 connecting the multi-SIM OBU to the CBC networks; instead to the multi-PLMN testbed in France).

6 ANNEX 2: Checklists

6.1 UCC#1: Advanced Driving

6.1.1 US#1.1.a: Complex Manoeuvres in cross-Border Settings: Lane Merge for Automated Vehicles (ES-PT)

Table 40: End-user devices in the Advanced Driving user stories in the ES-PT CBC

UE ID	Type of UE	UE host ID	UE host description
ES-PT_UE_01	OBU	ES-PT_veh_01	Citroën C4, autonomous
ES-PT_UE_03	OBU	ES-PT_veh_03	Volkswagen Golf, autonomous
ES-PT_UE_06	OBU	ES-PT_veh_06	PT Connected Vehicle
ES-PT_UE_07	RSU	ES-PT_radar_01	ES radar
ES-PT_UE_08	RSU	ES-PT_radar_02	PT radar

Table 41: MECs in the Advanced Driving user stories in the ES-PT CBC

MEC ID	Country	MNO ID	MEC Name
ES-PT_MEC_01	ES	ES-PT_MNO_02	MEC Calvario CT
ES-PT_MEC_02	PT	ES-PT_MNO_03	MEC Riba d'Ave

Table 42: applications in the Advanced Driving user stories in the ES-PT CBC

Application ID	Description	Installed in
ES-PT_veh_app_01	MQTT client	ES-PT_veh_01 ES-PT_veh_03 ES-PT_veh_06 ES-PT_radar_01 ES-PT_radar_02
ES-PT_veh_app_05	app for managing the info to perform the autonomous function	ES-PT_veh_03
ES-PT_radar_app_01	app for detecting the legacy vehicles	ES-PT_radar_01 ES-PT_radar_02
ES-PT_MEC_app_01	MQTT server	ES-PT_MEC_01

Application ID	Description	Installed in
		ES-PT_MEC_02

Table 43: Checklist for the Lane Merge user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	CTAG AtoBe IT	Pass	1) ES-PT_veh_01, ES-PT_veh_03 and ES-PT_veh_06 have 5G connectivity and the required CCAM functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_01 is installed in ES-PT_veh_01, ES-PT_veh_03 and ES-PT_veh_06 and it is ready for the tests 2) ES-PT_veh_app_05 is installed in ES-PT_veh_03 and ready for the tests
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG	Pass	The lidar and laser are dumping the object detection information to the CAN bus. It is checked by means of specific software (Canalyzer) and also visualized in the HMI
V5	The vehicle applications are correctly installed	CTAG	Pass	ES-PT_veh_app_05 is accessing all the required information to have the inputs to perform the autonomous function
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	CTAG	Pass	The same as V4
V7	Messages and data content and encoding has been agreed between partners.	CTAG	Pass	1) ES-PT_veh_app_01 has access to the CAN bus to get the GPS data to create the CAM messages 2) ES-PT_veh_app_05 receives the information to perform the autonomous function
V8	The vehicle has safety measures in place to allow the driver to take control	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_01 is publishing/subscribing in the MEC: - CAM - ETSI EN 302 637-2 V1.4.1 2) ES-PT_veh_app_01 is subscribing in the MEC: - CPM - ETSI TS 103 324
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	CTAG	Pass	Changing from autonomous driving to manual driving Pressing brake pedal Steering wheel torque over 6Nm Pushing the emergency button
OBU related issues				

ID	Issue	Partner(s)	Result	Explanation
V10	All OBUs are ready and available for the trials	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are provided by CTAG 2) ES-PT_UE_06 is provided by IT
V11	The OBUs are correctly installed in the CAV/CV	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are provided by CTAG 2) ES-PT_UE_06 is provided by IT
V12	The applications in the OBU behave as expected and are validated	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are located in the trunk, connected to the power supply of the vehicles using "banana plugs". The modem is connected to an antenna on the roof of the vehicle. 2) ES-PT_UE_06 is portable and is only installed in ES-PT_veh_06 when tests need to be run through a simple process (lighter power and exterior antennas connection only)
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are checked by means of a SSH connection to verify that all the processes are running 2) ES-PT_UE_06 is checked by means of a SSH connection to check that all the processes are running
V15	The OBUs connect and have access to the 5G network	CTAG, IT Nokia ES Nokia PT	Pass	Checked by a ping from ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 to ES-PT_MEC_01 and ES-PT_MEC_02
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	CTAG, IT Nokia ES Nokia PT	Pass	ES-PT_UE_01, ES_PT_UE_03 and ES-PT_UE_06: checked by accessing radio parameters of the modem and identifying ES-PT_MNO_02 and ES-PT_MNO_03 and the 5G bands
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	CTAG, IT Nokia ES Nokia PT	Pass	ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 are publishing and receiving messages to the ES-PT_ MEC_01 and ES-PT_MEC_02 (verified by means of the application and network logs)
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG, IT Nokia ES Nokia PT	Pass	1) ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 are publishing and receiving messages to/from the ES-PT_ MEC_01/ES-PT_MEC_02 in its cell and adjacent ones
V19	Synchronisation measures are used for the OBU	CTAG	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 use differential GPS positioning
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured	CTAG IT	Pass	1) CTAG provides ES-PT_radar_01 for the tests in the ES side 2) IT provides the traffic radars, IP cameras and 5G RSUs (ES-PT_radar_02) for the Portuguese side and all this equipment have been installed on the field.

ID	Issue	Partner(s)	Result	Explanation
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity	CTAG, IT Nokia ES Nokia PT	Pass	1) Checked by a ping from ES-PT_radar_01 to ES-PT_MEC_01 and from ES-PT_radar_02 to ES-PT_MEC_02 (averaged ping latency is 24ms)
I3	The infrastructure sensors connect and have access to the 5G network	CTAG IT	Pass	1) ES-PT_radar_01 and ES-PT_radar_02: checked by accessing radio parameters of the modem and identifying ES-PT_MNO_01 and ES-PT_MNO_03 and the 5G bands
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding	CTAG IT	Pass	1) ES-PT_radar_01 is sending CPM messages to ES-PT_MEC_01 and ES-PT_MEC_02 2) ES-PT_radar_02 is sending CPM messages to ES-PT_MEC_01 and ES-PT_MEC_02
I5	Synchronisation measures are used for the infrastructure	CTAG IT	Pass	1) ES-PT_radar_01 and ES-PT_radar_02 have implemented synchronization using NTP and PPS correction based on GNSS receivers.
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data	CTAG IT	Pass	1) ES-PT_radar_01 is sending CPM messages to ES-PT_MEC_01 and ES-PT_MEC_02 2) ES-PT_radar_02 is sending CPM messages to ES-PT_MEC_01 and ES-PT_MEC_02
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	CTAG IT Nokia ES Nokia PT	Pass	ES-PT_MEC_app_01 in ES-PT_MEC_01 and ES-PT_MEC_02 is publishing / subscribing CAM messages from / to ES-PT_UE_01 (ES-PT_veh_app_01), ES-PT_UE_03 (ES-PT_veh_app_01) and ES-PT_UE_06 (ES-PT_veh_app_01) and CPM messages from ES-PT_radar_01 and ES-PT_radar_02
N2	All partners have access to the needed interfaces and infrastructure	CTAG IT Nokia ES Nokia PT	Pass	The same as N1
N3	MEC applications can handle the relevant C-ITS messages	CTAG IT Nokia ES Nokia PT	Pass	The same as N1
N4	The complete test area is covered by the 5G-networks	Telefonica NOS Nokia ES Nokia PT	Pass	Tested with a coverage map

ID	Issue	Partner(s)	Result	Explanation
N5	MEC access is provided for the whole test area	Telefonica NOS Nokia ES Nokia PT	Pass	Tested running the ES-PT_MEC_app_01 and ES-PT_UE_app_01
N6	All MEC applications and data logging are synchronised	Telefonica NOS Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 have implemented synchronization using NTP
N7	Data is exchanged between MECs through agreed protocols	CTAG IT	Pass	- CAM - ETSI EN 302 637-2 V1.4.1 - CPM - ETSI TS 103 324
N8	The algorithms for geolocation and filtering of messages work as expected	CTAG IT	Pass	Tested and working as expected with zoom 18 in the MECs and publishing/subscribing to the own and the neighbouring cells
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests satisfactory by using the OBUs with US data
N10	MEC1 can connect with MEC2 and vice-versa	Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 interchanges ETSI C-ITS messages
N11	The UEs can roam between MNO1 and MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests with home routed already executed satisfactorily in both directions (ES-PT and PT-ES)
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	CTAG IT Nokia ES Nokia PT	Pass	1) ES-PT_MEC_01 and ES-PT_MEC_02 are VPN 2) ES-PT_MEC_app_01 is a MQTT over TLS
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Not relevant	There is no certificate exchange for C-ITS messages. Access to network is granted through provisioning SIM cards.
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)		Not relevant	No ETSI ITS geonet headers are used, just ITS messages payload protected by MQTT over TLS. Interoperability is being tested at the time of writing.

ID	Issue	Partner(s)	Result	Explanation
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Not relevant	There is no storage of such data.
Logging related issues				
L1	Logging is in place for all components	CTAG IT	Pass	TFT1.1.1-CAM: CAM messages between connected vehicles and MEC TFT1.1.2-CPM_UL: CPM messages from radar to MEC TFT1.1.3-CPM_DL: CPM messages from MEC to host vehicle
L2	Procedures for starting logging are in place	CTAG IT	Not relevant	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format	CTAG IT	Pass	The tools to convert the raw data into the common data format are developed
L4	Logged data can be uploaded to the CTS	CTAG IT	Pass	First test with no evaluation data already upload to validate the process
L5	All data required is logged	CTAG IT	Pass	1) ES-PT_veh_app_01 in ES-PT_veh_01, ES_PT_veh_03, ES_PT_veh_06 is logging as expected 2) ES-PT_MEC_app_01 in ES-PT_MEC_01 and ES-PT_MEC_02 is logging as expected
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	CTAG IT	Pass	1) ES-PT_veh_01, ES_PT_veh_03 and ES-PT_veh_06 are synchronized 2) ES-PT_MEC_01 and ES-PT_MEC_02 are synchronized

6.1.2 US#1.1.b: Complex Manoeuvres in Cross-Border Settings: Overtaking (ES-PT)

Table 44: Checklist for the Overtaking user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	CTAG AtoBe IT	Pass	1) ES-PT_veh_01, ES-PT_veh_03 and ES-PT_veh_06 have 5G connectivity and the required CCAM functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_01 is installed in ES-PT_veh_01, ES-PT_veh_03 and ES-PT_veh_06 and it is ready for the tests 2) ES-PT_veh_app_05 is installed in ES-PT_veh_03 and ready for the tests

ID	Issue	Partner(s)	Result	Explanation
V3	The physical components, integrated in the vehicle, send the correct information	CTAG	Pass	The lidar and laser are dumping the object detection information to the CAN bus. It is checked by means of specific software (Canalyzer) and also visualized in the HMI
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG	Pass	ES-PT_veh_app_05 is accessing all the required information to have the inputs to perform the autonomous function
V5	The vehicle applications are correctly installed	CTAG AtoBe IT	Pass	The same as V4
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	CTAG	Pass	1) ES-PT_veh_app_01 has access to the CAN bus to get the GPS data to create the CAM messages 2) ES-PT_veh_app_05 receives the information to perfom the autonomous function
V7	Messages and data content and encoding have been agreed between partners.	CTAG AtoBe IT	Pass	ES-PT_veh_app_01 is publishing/subscribing in the MEC: - CAM - ETSI EN 302 637-2 V1.4.1
V8	The vehicle has safety measures in place to allow the driver to take control	CTAG	Pass	Changing from autonomous driving to manual driving Pressing brake pedal Steering wheel torque over 6Nm Pushing the emergency button
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	CTAG AtoBe IT	Pass	The national traffic authorities in ES and PT have provided time slots to perform the final tests in open road but the verification tests are performed in a controlled environment for safety reasons
OBU related issues				
V10	All OBUs are ready and available for the trials	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are provided by CTAG 2) ES-PT_UE_06 is provided by IT
V11	The OBUs are correctly installed in the CAV/CV	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are located in the trunk, connected to the power supply of the vehicles using "banana plugs". The modem is connected to an antenna on the roof of the vehicle. 2) ES-PT_UE_06 is portable and is only installed in ES-PT_veh_06 when tests need to be run through a simple process (lighter power and exterior antennas connection only)

ID	Issue	Partner(s)	Result	Explanation
V12	The applications in the OBU behave as expected and are validated	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are checked by means of a SSH connection to verify that all the processes are running 2) ES-PT_UE_06 is checked by means of a SSH connection to check that all the processes are running
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	CTAG IT Nokia ES Nokia PT	Pass	Checked by a ping from from ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 to ES-PT_MEC_01 and ES-PT_MEC_02
V15	The OBUs connect and have access to the 5G network	CTAG IT Telefónica NOS	Pass	ES-PT_UE_01, ES_PT_UE_03 and ES-PT_UE_06: checked by accessing radio parameters of the modem and identifying ES-PT_MNO_02 and ES-PT_MNO_03 and the 5G bands
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	CTAG IT Nokia ES Nokia PT	Pass	ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 are publishing and receiving messages to the ES-PT_ MEC_01 and ES-PT_MEC_02 (verified by means of the application and network logs)
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	CTAG IT Nokia ES Nokia PT	Pass	1) ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 are publishing and receiving messages to/from the ES-PT_ MEC_01/ES-PT_MEC_02 in its cell and adjacent ones
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 use differential GPS positioning
V19	Synchronisation measures are used for the OBU	CTAG IT	Pass	1) ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 have implemented synchronization using NTP and PPS correction based on GNSS receivers
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	CTAG IT Nokia ES Nokia PT	Pass	ES-PT_MEC_app_01 in ES-PT_MEC_01 and ES-PT_MEC_02 is publishing / subscribing CAM messages from / to ES-PT_UE_01 (ES-PT_veh_app_01), ES-PT_UE_03 (ES-PT_veh_app_01) and ES-PT_UE_06 (ES-PT_veh_app_01)
N2	All partners have access to the needed interfaces and infrastructure	CTAG IT Nokia ES Nokia PT	Pass	The same as N1

ID	Issue	Partner(s)	Result	Explanation
N3	MEC applications can handle the relevant C-ITS messages	CTAG IT Nokia ES Nokia PT	Pass	The same as N1
N4	The complete test area is covered by the 5G-networks	Telefonica NOS Nokia ES Nokia PT	Pass	Tested with a coverage map
N5	MEC access is provided for the whole test area	Telefonica NOS Nokia ES Nokia PT	Pass	Tested running the ES-PT_MEC_app_01 and ES-PT_UE_app_01
N6	All MEC applications and data logging are synchronised	Telefonica NOS Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 have implemented synchronization using NTP
N7	Data is exchanged between MECs through agreed protocols	CTAG IT	Pass	- CAM - ETSI EN 302 637-2 V1.4.1
N8	The algorithms for geolocation and filtering of messages work as expected	CTAG IT	Pass	Tested and working as expected with zoom 18 in the MECs and publishing/subscribing to the own and the neighbouring cells
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests satisfactory by using the OBUs with US data
N10	MEC1 can connect with MEC2 and vice-versa	Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 interchanges ETSI C-ITS messages
N11	The UEs can roam between MNO1 and MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests with home routed already executed satisfactorily in both directions (ES-PT and PT-ES)
Privacy and security issues				

ID	Issue	Partner(s)	Result	Explanation
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	CTAG IT Nokia ES Nokia PT	Pass	1) ES-PT_MEC_01 and ES-PT_MEC_02 are VPN 2) ES-PT_MEC_app_01 is a MQTT over TLS
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Not relevant	There is no certificate exchange for C-ITS messages. Access to network is granted through provisioning SIM cards.
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)		Not relevant	No ETSI ITS geonet headers are used, just ITS messages payload protected by MQTT over TLS. Interoperability is being tested at this time.
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Not relevant	There is no storage of such data.
Logging related issues				
L1	Logging is in place for all components	CTAG IT	Pass	TFT1.1.1-CAM: CAM messages between connected vehicles and MEC
L2	Procedures for starting logging are in place		Not relevant	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format	CTAG IT	Pass	The tools to convert the raw data into the common data format are developed
L4	Logged data can be uploaded to the CTS	CTAG IT	Pass	First test with no evaluation data already upload to validate the process
L5	All data required is logged	CTAG IT	Pass	1) ES-PT_veh_app_01 in ES-PT_veh_01, ES_PT_veh_03, ES_PT_veh_06 is logging as expected 2) ES-PT_MEC_app_01 in ES-PT_MEC_01 and ES-PT_MEC_02 is logging as expected
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	CTAG IT	Pass	1) ES-PT_veh_01, ES_PT_veh_03 and ES-PT_veh_06 are synchronized 2) ES-PT_MEC_01 and ES-PT_MEC_02 are synchronized

6.1.3 US#1.2: Infrastructure-Assisted Advanced Driving (FR)

Table 45: Checklist for the Infrastructure Assisted Advanced Driving user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	VEDECOM	Pass	VEDECOM CAV vehicle is available for tests
V2	The physical components are integrated and operate correctly	VEDECOM	Pass	The 5G OBU as well sensors (LiDARs, camera) are integrated in the vehicle, and connects to the networks available in Satory (4G network)
V3	The physical components, integrated in the vehicle, send the correct information	VEDECOM	Pass	The sensors in the vehicle have been tested with various situations of highway insertion. 5G OBU connectivity connects correctly to the networks and send CAM/CPM messages
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	VEDECOM	Pass	The lane change manoeuvre has been tested with sending an MCM to the CAV. The vehicle behaves as expected.
V5	The vehicle applications are correctly installed	VEDECOM	Pass	Applications are working fine
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	VEDECOM	Pass	The vehicles build the CPM/MCM messages using dynamic sensor values
V7	Messages and data content and encoding have been agreed between partners.	VEDECOM	Pass	Messages are compliant with the European standards, otherwise specification defined in the project.
V8	The vehicle has safety measures in place to allow the driver to take control	VEDECOM	Pass	The vehicle has an emergency button with which the automated driving can be interrupted immediately and manual braking overrides automated vehicle control. Only professional driver (authorised persons) drive the vehicle.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received		Not relevant	testing on a closed test site, no permits needed
OBU related issues				
V10	All OBUs are ready and available for the trials	VEDECOM	Partly	Six 5G OBUs (3 VEDECOM and 3 VALEO) are available for tests under 5G cmWave networks. OBUs for mmWave have been developed, its functionalities are being validated.

ID	Issue	Partner(s)	Result	Explanation
V11	The OBUs are correctly installed in the CAV/CV	VEDECOM	Pass	yes, the OBU is correctly installed in the vehicles.
V12	The applications in the OBU behave as expected and are validated	VEDECOM	Pass	The applications in the OBU, particularly V2X applications and KPI agent, predictive QoS agent, behave as expected.
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	VEDECOM, CATAPULT	Partly	OBU is connected through 4G/5G to the MEC. Connection using 5G mmWave will be tested.
V15	The OBUs connect and have access to the 5G network	VEDECOM	Partly	5G OBU tested with Bouygues and Orange 5G networks. Connection to 5G mmWave is being tested.
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	VEDECOM	Pass	OBUs transmit and receive CAM, CPM, MCM and MAPEM from the MEC
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	VEDECOM	Pass	CAV receives CPM and MCM from the MEC
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	VEDECOM	Pass	OBU is using GPS-RTK of the vehicle
V19	Synchronisation measures are used for the OBU	VEDECOM	Pass	using NTP server for synchro
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured	VEDECOM	Pass	LiDARs, cameras are installed at Satory
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity		Not relevant	sensor data is sent to the MEC through optical fibre
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding	VEDECOM	Pass	LiDARs are able to send object list detected
I5	Synchronisation measures are used for the infrastructure	VEDECOM	Pass	NTP server is used
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data	VEDECOM	Pass	Applications are working file on a PC used as a MEC.

ID	Issue	Partner(s)	Result	Explanation
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	VEDECOM, CATAPULT	Pass	VEDECOM has developed MEC/cloud applications. The functionalities are tested. Catapult has developed cloud server in which VEDECOM's applications are integrated. Tests were successful.
S2	External servers are connected to the network and accessible by all partners needing access	VEDECOM, CATAPULT	Pass	Yes, via public IP
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	VEDECOM, CATAPULT	Pass	For the remote centre, risk analysis and HMI applications have been installed and validated.
S4	Messages with the servers can be exchanged according to the relevant specifications	VEDECOM	Pass	Messages with servers can be exchanged according to the ETSI specifications.
S5	Synchronisation measures are used for the server	VEDECOM, CATAPULT	Pass	NTP server is used
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	VEDECOM, CATAPULT	Pass	VEDECOM applications running on Catapult's cloud server.
N2	All partners have access to the needed interfaces and infrastructure	VEDECOM, CATAPULT	Pass	The MEC server (a public IP with VPN) servers are accessible
N3	MEC applications can handle the relevant C-ITS messages	VEDECOM	Pass	Yes, MEC can handle C-ITS messages particularly CAM, CPM, MCM, and MAP.
N4	The complete test area is covered by the 5G-networks	VEDECOM, ORANGE, BOUYGUES	Partly	TEQMO and SATORY are totally covered by 5G cmWave 5G mmWave functionality at will be tested.
N5	MEC access is provided for the whole test area	VEDECOM	Pass	MEC servers are installed in Teqmo and Satory, providing access to the whole test areas.
N6	All MEC applications and data logging are synchronised	VEDECOM	Pass	NTP server
N7	Data is exchanged between MECs through agreed protocols	VEDECOM	Pass	via MQTT
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	VEDECOM, CATAPULT	Pass	Multi-SIM OBU is used

ID	Issue	Partner(s)	Result	Explanation
N10	MEC1 can connect with MEC2 and vice-versa	VEDECOM	Pass	Via MQTT
N11	The UEs can roam between MNO1 and MNO2		Not relevant	Roaming is not allowed in France.
Logging related issues				
L1	Logging is in place for all components	VEDECOM	Pass	The logging functions are developed and integrated in each component
L2	Procedures for starting logging are in place	VEDECOM	Pass	Yes, KPI manager is in place
L3	Logging formats comply with the agreed format	VEDECOM	Pass	Yes, logging formats comply the common data formats
L4	Logged data can be uploaded to the CTS	VEDECOM	Pass	Yes, data can be uploaded to the CTS
L5	All data required is logged	VEDECOM	Party	Trials are ongoing
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	VEDECOM	Pass	Yes, systems are synchronised.

6.1.4 US#1.3: Cooperative Collision Avoidance (NL)

Table 46: Checklist for the Cooperative Collision Avoidance user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	VTT	Pass	The test vehicle Martti is available for the tests and is agreed to be transported to the Netherlands for the trials. COVID-19 related restrictions may delay the availability at the test site.
V2	The physical components are integrated and operate correctly	VTT	Pass	The OBU is integrated in the vehicle and connects to the networks available in Tampere. No additional sensors have been installed.
V3	The physical components, integrated in the vehicle, send the correct information	VTT	Pass	The sensors in the vehicle have been tested with various obstacles in Tampere. The sensors are able to detect obstacles and make the information available on the vehicle's network
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	VTT	Pass	The CoCa algorithm has been tested in the Pirkkala karting test track, and works as expected. The information is transmitted using the MQTT in the format agreed.

ID	Issue	Partner(s)	Result	Explanation
V5	The vehicle applications are correctly installed	VTT	pass	The applications run without failure. They have been tested in Pirkkala during tests with OBUs installed in both the Martti vehicle and on a motorcycle.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	VTT	pass	The vehicles build the MCM messages using dynamic sensor values.
V7	Messages and data content and encoding have been agreed between partners.	VTT	pass	MCM messages are only used by VTT. The MCM is based on the version used by the TRANSAID project.
V8	The vehicle has safety measures in place to allow the driver to take control	VTT	pass	The vehicle has an emergency button with which the automated driving can be interrupted immediately and manual braking overrides automated vehicle control.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	VTT	pass	The vehicle has the permission to drive on public roads in automated mode in Finland. In the Netherlands, the vehicle will only drive in automated mode in a closed area - hence not subject to specific permits.
OBU related issues				
V10	All OBUs are ready and available for the trials	VTT	Pass	The Huawei modem, which was used in the tests in Tampere on commercial NSA networks (and according to specs also supports SA), did not attach to the SA networks in Netherlands, and has been replaced with a Netgear modem.
V11	The OBUs are correctly installed in the CAV/CV	VTT	Pass	The OBU is integrated in the Martti vehicle. In the other vehicle, a standalone OBU will be used. This OBU has been developed by VTT and has been tested in the motorcycle. The modem was changed with a Netgear modem to connect to the Dutch SA networks
V12	The applications in the OBU behave as expected and are validated	VTT	Pass	The application has been tested on the test track in Pirkkala. The demonstration was successful.
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	VTT	Not relevant	
V15	The OBUs connect and have access to the 5G network	VTT	Pass	Tested in the Dutch SA networks in July and August 2021. The OBUs transmit and receive data from the MECs
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	VTT	Pass	The Huawei modem was replaced with a Netgear modem, which connects to both the TNO and KPN networks.

ID	Issue	Partner(s)	Result	Explanation
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	VTT	Pass	Tested in Pirkkala. See test V7
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	VTT	Pass	Tested in Pirkkala, but no filtering was applied. Tested in the Netherlands
V19	Synchronisation measures are used for the OBU	VTT	Pass	Use of RTK has been tested in Finland and Netherlands.
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	VTT, TNO, KPN	Pass	The MEC application have been deployed on the MEC in the TNO network.
N2	All partners have access to the needed interfaces and infrastructure	VTT, TNO, KPN	Pass	The MEC application is only used by VTT.
N3	MEC applications can handle the relevant C-ITS messages	VTT	Pass	The MEC application has been tested in Pirkkala.
N4	The complete test area is covered by the 5G-networks	VTT, TNO, KPN	Pass	Tests have been performed by TNO to test the coverage of both TNO and KPN in the Vaarle parking area.
N5	MEC access is provided for the whole test area	VTT, TNO, KPN	Pass	Same as N4.
N6	All MEC applications and data logging are synchronised	VTT	Pass	chrony is used
N7	Data is exchanged between MECs through agreed protocols	VTT, TNO	Pass	Use of MQTT, and MCM, encoded in ASN.1/UPER
N8	The algorithms for geolocation and filtering of messages work as expected	VTT	Pass	The expected messages are received
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Not relevant	No handover during CoCa
N10	MEC1 can connect with MEC2 and vice-versa	VTT, TNO, KPN	Pass	The complete information chain between the TNO and KPN networks
N11	The UEs can roam between MNO1 and MNO2		Not relevant	No roaming in the user story.
Privacy and security issues				

ID	Issue	Partner(s)	Result	Explanation
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	VTT	Pass	No privacy related data exchanged.
Logging related issues				
L1	Logging is in place for all components	VTT	Pass	Log files have been generated.
L2	Procedures for starting logging are in place	VTT	Pass	Tested in Tampere and the Netherlands.
L3	Logging formats comply with the agreed format	VTT	Partly	Some differences in the logging format
L4	Logged data can be uploaded to the CTS	VTT	Not tested	
L5	All data required is logged	VTT	Pass	Verified with TNO
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	VTT	Pass	Verified

6.1.5 US#1.4: Cloud-Assisted Advanced Driving (CN)

Table 47: Checklist for the Cloud-Assisted Advanced Driving user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	SDIA	Pass	CN_veh_01 was ready with OBU, and CN_veh_02 will be ready in April-27
V2	The physical components are integrated and operate correctly	SDIA, DATANG	Pass	Physical components integration with CN_veh_01 was ready.
V3	The physical components, integrated in the vehicle, send the correct information	SDIA, DATANG	Pass	Physical components integration with CN_veh_01 was ready.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	SDIA, DATANG	Pass	After readiness of CN_veh_02 and MQTT client, tests among CN_veh_01, CN_veh_02 and will be initiated.
V5	The vehicle applications are correctly installed	SDIA, DUT	Pass	The applications was developed and tested successfully by DUT.

ID	Issue	Partner(s)	Result	Explanation
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	SDIA	Pass	The vehicle application has access to partly required data in real time
V7	Messages and data content and encoding have been agreed between partners.	SDIA, DUT	Pass	Agreed.
V8	The vehicle has safety measures in place to allow the driver to take control	SDIA	Pass	The drivers can take over control from the automated vehicle in critical situations with braking or steering the wheel
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	All CN partners	Pass	All the necessary permissions have been given for the tests.
OBU related issues				
V10	All OBUs are ready and available for the trials	DATANG, SDIA	Pass	DATANG provides the OBUs and currently are at SDIA for the integration with their vehicles
V11	The OBUs are correctly installed in the CAV/CV	DATANG, SDIA	Pass	CN_veh_01 is correctly installed with OBU
V12	The applications in the OBU behave as expected and are validated	DATANG, SDIA	Pass	DATANG has tested the OBU before sending it to the SDIA
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	SDIA, DATANG	Pass	The OBUs have a live connection to MEC over 4G/5G connectivity
V15	The OBUs connect and have access to the 5G network	DATANG	Pass	DATANG has tested 5G connection of the OBU in Shanghai city
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	DATANG, SDIA	Pass	5G OBU connectivity in this US is not tested yet
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	SDIA, DUT	Pass	Geolocation messaging components implementation is in progress.
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	BeiDou component is employed for positioning.

ID	Issue	Partner(s)	Result	Explanation
V19	Synchronisation measures are used for the OBU	All CN partners	Pass	A confirmed NTP server is used for all CN partners
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured	SDIA	Pass	The availability of the infrastructure sensors was tested.
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity	SDIA,DATANG	Pass	The infrastructure sensors have live connection to MEC over 4G/5G connectivity
I3	The infrastructure sensors connect and have access to the 5G network	SDIA,DATANG	Pass	The infrastructure sensors connect and have access to the 5G network
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding	SDIA,DATANG	Pass	Related standard messages have been tested
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data	SDIA	Pass	Applications at the infrastructure (edge) worked correctly and had real-time access to all required data
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	SDIA, DUT	Pass	External servers and software, which are needed for the user story, are available
S2	External servers are connected to the network and accessible by all partners needing access	SDIA	Pass	SDIA has tested the connection and accessibility of the servers
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	SDIA	Pass	The applications on the external servers have been installed correctly
S4	Messages with the servers can be exchanged according to the relevant specifications	DUT, SDIA	Pass	Messages with the servers can be exchanged
S5	Synchronisation measures are used for the server	All CN partners	Pass	
5G network related issues (incl. MEC issues)				

ID	Issue	Partner(s)	Result	Explanation
N2	All partners have access to the needed interfaces and infrastructure	All CN partners	Pass	
N3	MEC applications can handle the relevant C-ITS messages	SDIA	Pass	
N4	The complete test area is covered by the 5G-networks	SDIA	Pass	
N5	MEC access is provided for the whole test area	SDIA	Pass	MEC access is provided for the whole test area
N6	All MEC applications and data logging are synchronised	SDIA,DUT	Pass	
Privacy and security issues				
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	All CN partners	Pass	Required components were ready
Logging related issues				
L1	Logging is in place for all components	DUT, SDIA	Pass	logging in on-board computer of vehicle and cloud server for controller message has been tested.
L2	Procedures for starting logging are in place	DUT, SDIA	Pass	Related messages will be logged at the onboard computer in the vehicle
L3	Logging formats comply with the agreed format	DUT, SDIA	Not tested	Required components are not ready
L4	Logged data can be uploaded to the CTS	DUT, SDIA	Not tested	Required components are not ready
L5	All data required is logged	DUT, SDIA	Partly	Required components are not ready
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	All CN partners	Pass	Required components were ready

6.1.6 US#1.5: Automated Shuttle Driving Across Borders: Cooperative Automated System (ES-PT)

Table 48: End-user devices in the automated shuttle user stories in the ES-PT CBC

UE ID	Type of UE	UE host ID	UE host description

ES-PT_UE_04	OBU	ES-PT_veh_04	CTAG autonomous shuttle
ES-PT_UE_09	smartphone	ES-PT_VRU_01	VRU
ES-PT_UE_12	RSU	ES-PT_cam_03	ES pedestrian detector system
ES-PT_UE_13	RSU	ES-PT_cam_04	PT pedestrian detector system

Table 49: MECs in the automated shuttle user stories in the ES-PT CBC

MEC ID	Country	MNO ID	MEC Name
ES-PT_MEC_01	ES	ES-PT_MNO_02	MEC Calvario CT
ES-PT_MEC_02	PT	ES-PT_MNO_03	MEC Riba d'Ave

Table 50: Applications in the automated shuttle user stories in the ES-PT CBC

Application ID	Description	Installed in
ES-PT_veh_app_01	MQTT client	ES-PT_veh_04 ES-PT_cam_03 ES-PT_cam_04
ES-PT_veh_app_05	app for managing the info to perform the autonomous function	ES-PT_veh_04
ES-PT_radar_app_01	Collision detection system	ES-PT_cam_03 ES-PT_cam_04
ES-PT_MEC_app_01	MQTT server	ES-PT_MEC_01 ES-PT_MEC_02

Table 51: Checklist for the Cooperative Automated System user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	CTAG	Pass	ES-PT_veh_04 has 5G connectivity and the required CCAM functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG	Pass	ES-PT_veh_app_01 and ES_PT_veh_app_05 are installed in ES-PT_veh_04 and are ready for the tests
V3	The physical components, integrated in the vehicle, send the correct information	CTAG	Pass	ES-PT_veh_04: the lidar and the camera are dumping the object detection information to the CAN bus. It is checked by means of specific software (Canalyzer) and also visualized in the HMI

ID	Issue	Partner(s)	Result	Explanation
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG	Pass	ES-PT_veh_04 is accessing all the required information via CAN and is able to perform the autonomous function
V5	The vehicle applications are correctly installed	CTAG	Pass	The same as V4
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	CTAG	Pass	1) ES-PT_veh_app_01 has access to the CAN bus to get the GPS data to create the CAM messages 2) ES-PT_veh_app_05 receives the information to perform the autonomous function
V7	Messages and data content and encoding has been agreed between partners.	CTAG	Pass	ES-PT_veh_04 is publishing and/or subscribing in the MEC: - CAM - ETSI EN 302 637-2 V1.4.1 - DENM - ETSI EN 302 637-3 V1.3.1
V8	The vehicle has safety measures in place to allow the driver to take control	CTAG	Pass	Changing from autonomous driving to manual driving Pushing the emergency button
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	CTAG CCG	Pass	The national traffic authorities in ES and PT have provided time slots to perform the final tests in open road but the verification tests are performed in a controlled environment for safety reasons
OBU related issues				
V10	All OBUs are ready and available for the trials	CTAG	Pass	ES-PT_UE_04 is provided by CTAG
V11	The OBUs are correctly installed in the CAV/CV	CTAG	Pass	ES-PT_UE_04 is located under the seats, connected to the power supply of the shuttle using "banana plugs". The modem is connected to an antenna on the roof of the vehicle.
V12	The applications in the OBU behave as expected and are validated	CTAG	Pass	ES-PT_UE_04 is checked by means of a SSH connection to verify that all the processes are running
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	No 3rd party CCAM applications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	CTAG Nokia ES Nokia PT	Pass	Checked by a ping from ES-PT_UE_04 to ES-PT_MEC_01 and ES-PT_MEC_02
V15	The OBUs connect and have access to the 5G network	CTAG Nokia ES Nokia PT	Pass	ES-PT_UE_04: checked by accessing radio parameters of the modem and identifying ES-PT_MNO_01 and ES-PT_MNO_03 and the 5G bands

ID	Issue	Partner(s)	Result	Explanation
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	CTAG Nokia ES Nokia PT	Pass	ES-PT_UE_04 are publishing and receiving messages to the ES-PT_ MEC_01 (verified by means of the application logs)
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)		Pass	1) ES-PT_UE_04 is publishing and receiving messages to the ES-PT_ MEC_01 in its cell
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG	Pass	ES-PT_UE_04 uses differential GPS positioning
V19	Synchronisation measures are used for the OBU		Pass	ES-PT_UE_04 has implemented synchronization using NTP and PPS correction and was checked by means of the application logs in both OBUs getting a stable latency of 100ms
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured	CTAG Siemens	Pass	ES-PT_cam_03 is provided by CTAG ES-PT_cam_04 is provided by Siemens
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity	CTAG	Pass	Checked by a ping from ES-PT_UE_12/ES-PT_UE_13 to ES-PT_MEC_01 (averaged ping latency is 24ms).
I3	The infrastructure sensors connect and have access to the 5G network	CTAG	Pass	ES-PT_UE_12 and ES-PT_UE_13 are checked by accessing radio parameters of the modem and identifying ES-PT_MNO_01 and the 5G bands
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding	CTAG	Pass	ES-PT_UE_12 and ES-PT_UE_13 are publishing in the MEC: - DENM - ETSI EN 302 637-3 V1.3.1
I5	Synchronisation measures are used for the infrastructure	CTAG	Pass	ES-PT_UE_12 and ES-PT_UE_13 have implemented synchronization using NTP and PPS correction
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data	CTAG	Pass	ES-PT_cam_01 is providing the proper data to ES-PT_UE_12 to build the DENM messages ES-PT_cam_02 is providing the proper data to ES-PT_UE_13 to build the DENM messages
Other end user devices (e.g. VRUs, smartphones)				
E1	Other end user devices, which are needed for the user story, are available	CCG	Pass	ES-PT_UE_09 is provided by CCG.

ID	Issue	Partner(s)	Result	Explanation
E2	End user devices are connected to the network	CCG	Pass	ES-PT_UE_09 was able to send CAM messages to a remote broker
E3	The end-user devices have live connection to MEC over 4G/5G connectivity	CCG	Pass	ES-PT_UE_09 was able to send CAM messages to a remote broker
E4	The application algorithms on the end-user device are installed correctly and work as expected	CCG	Partly	ES-PT_UE_09 is able to send CAM messages to the broker. Some issues with sending frequency detected.
E5	The end-user devices are capable to transmit the relevant (C-ITS) messages according to the relevant standard and encoding	CCG	Pass	- CAM - ETSI EN 302 637-2 V1.4.1 - DENM - ETSI EN 302 637-3 V1.3.1
E6	Synchronisation measures are used for the server	CCG	Not tested	Synchronization will be achieved through NTP.
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	CTAG IT Nokia ES Nokia PT	Pass	1) ES-PT_MEC_app_01 (provided by CTAG on ES side) in ES-PT_MEC_01 (hosted by Nokia ES on ES side) and ES-PT_MEC_app_01 (provided by IT on PT side) in ES-PT_MEC_01 (hosted by Nokia PT on PT side) is publishing / subscribing CAM messages from ES-PT_UE_01 (ES-PT_veh_app_01), ES-PT_UE_03 (ES-PT_veh_app_01) and ES-PT_UE_06 (ES-PT_veh_app_01)
N2	All partners have access to the needed interfaces and infrastructure	CTAG IT Nokia ES Nokia PT	Pass	The same as N1
N3	MEC applications can handle the relevant C-ITS messages	CTAG IT Nokia ES Nokia PT	Pass	The same as N1
N4	The complete test area is covered by the 5G-networks	Telefonica NOS Nokia ES Nokia PT	Pass	Tested with a coverage map

ID	Issue	Partner(s)	Result	Explanation
N5	MEC access is provided for the whole test area	Telefonica NOS Nokia ES Nokia PT	Pass	Tested running the ES-PT_MEC_app_01 and ES-PT_UE_app_01
N6	All MEC applications and data logging are synchronised	Telefonica NOS Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 have implemented synchronization using NTP
N7	Data is exchanged between MECs through agreed protocols	CTAG IT	Pass	- CAM - ETSI EN 302 637-2 V1.4.1 - DENM - ETSI EN 302 637-3 V1.3.1
N8	The algorithms for geolocation and filtering of messages work as expected	CTAG IT	Pass	Tested and working as expected with zoom 18 in the MECs and publishing/subscribing to the own and the neighbouring cells
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Pass	First tests satisfactory by using the OBUs with US data
N10	MEC1 can connect with MEC2 and vice-versa		Pass	ES-PT_MEC_01 and ES-PT_MEC_02 interchanges ETSI C-ITS messages
N11	The UEs can roam between MNO1 and MNO2		Pass	First tests with home routed already executed satisfactorily in both directions (ES-PT and PT-ES)
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS …		Pass	1) ES-PT_MEC_01 and ES-PT_MEC_02 are VPN 2) ES-PT_MEC_app_01 is a MQTT over TLS
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Not relevant	There is no certificate exchange for C-ITS messages. Access to network is granted through provisioning SIM cards
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)		Not relevant	No ETSI ITS geonet headers are used, just ITS messages payload protected by MQTT over TLS. Interoperability is being tested at this time.
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Not relevant	There is no storage of such data.

ID	Issue	Partner(s)	Result	Explanation
Logging related issues				
L1	Logging is in place for all components	CTAG IT	Pass	TFT 1.3.1-CAM: CAM messages between shuttle and MEC - ES-PT_UE_04: CAM messages sent and received - ES-PT-MEC_01 / ES-PT_MEC_02: CAM messages sent and received TFT 1.3.2-DENM: CAM messages from VRU to MEC - ES-PT_UE_09: CAM messages sent - ES-PT_MEC_01 / ES-PT_MEC_02: CAM messages received TFT 1.3.3-DENM: DENM messages from camera to MEC - ES-PT_UE_12 / ES-PT_UE_13: DENM messages sent - ES-PT_MEC_01 / ES-PT_MEC_02: DENm messages received TFT 1.3.4-DENM: DENM messages from MEC to shuttle - ES-PT_MEC_01 / ES-PT_MEC_02: DENm messages sent - ES-PT_UE_04: DENM messages received
L2	Procedures for starting logging are in place	CTAG IT	Not relevant	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format	CTAG, IT	Pass	The tools to convert the raw data into the common data format are developed
L4	Logged data can be uploaded to the CTS	CTAG	Pass	First test with no evaluation data already upload to validate the process
L5	All data required is logged		Pass	1) ES-PT_veh_app_01 in ES-PT_UE_04 and ES-PT_UE_12 and ES-PT_cam_03 and ES-PT_cam_04 are logging as expected 2) ES-PT_MEC_app_01 in ES-PT_MEC_01 and ES-PT_MEC_02 are logging
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	1) ES-PT_UE_04 and ES-PT_UE_12 are synchronized 2) ES-PT_MEC_01 and ES-PT_MEC_02 are synchronized

6.2 UCC#2: Vehicles Platooning

6.2.1 US#2.1.a: Platooning with "See What I See" Functionality in Cross-Border Settings (GR-TR)

Table 52 User story of the See What I See user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				

ID	Issue	Partner(s)	Result	Explanation
V1	All CAVs are ready and available for the trials	FORD	Not relevant	The vehicles are ready and their transfer and deployment at the trial site is currently in progress for the ongoing trials.
V2	The physical components are integrated and operate correctly	FORD, IMEC, WINGS	Pass	Physical components integration with the vehicle is currently in progress.
V3	The physical components, integrated in the vehicle, send the correct information	FORD, IMEC, WINGS	Pass	Physical components integration with the vehicle was done.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	FORD, ICCS	Pass	Border-crossing tests are pending
V5	The vehicle applications are correctly installed	FORD	Pass	It has to be tested when the application will have been installed to the vehicle through OBUs.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	FORD	Pass	It has to be tested when the application will have been installed to the vehicle through OBUs.
V7	Messages and data content and encoding have been agreed between partners.	FORD, ICCS, IMEC, WINGS	Pass	SWIS application messages, data content and encoding have been shared with the partners (UDP control commands, video frames etc).
V8	The vehicle has safety measures in place to allow the driver to take control	FORD	Not relevant	The driver can take over control from the automated vehicle in critical situations with braking or steering the wheel.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	All partners	Pass	All the necessary permissions have been given for the tests.
OBU related issues				
V10	All OBUs are ready and available for the trials	IMEC, WINGS	Pass	IMEC provides the OBUs and currently are at Ford for the integration with their vehicles
V11	The OBUs are correctly installed in the CAV/CV	IMEC, FORD, WINGS	Pass	IMEC, FORD and WINGS are the partners involved in OBUs installation process which is currently in progress
V12	The applications in the OBU behave as expected and are validated	IMEC, ICCS	Pass	ICCS application will be connected with the respective OBU. Its separate operation has been locally tested in the lab and a 5G testbed. Its function, after the connection with OBUs, is pending for the ingoing trial.
V15	The OBUs connect and have access to the 5G network	IMEC, WINGS, COSMOTE, TURKCELL	Not relevant	Verified for GR-TR_UE_02 over the Cosmote 5G-Testbed in Athens (identical to the one in the borders)

ID	Issue	Partner(s)	Result	Explanation
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	IMEC, WINGS	Not relevant	IMEC and WINGS tests will assure this. From WINGS side, DENM and CAM messages have been used for communication between the OBU and the platform. Successful transmission/reception on both ends has ben verified.
V19	Synchronisation measures are used for the OBU	All partners	Not relevant	Specific UTP Servers have been identified and used for all GR-TR partners
Infrastructure related issues				
I5	Synchronisation measures are used for the infrastructure	All partners	Pass	Cosmote uses the NTP server of Google, and this server synchronizes the RAN (not GPS). The accuracy/offset of this method is being assessed. At Turkcell, GPS is used to synchronize the NTP server. Specific UTP Servers have been identified and used for all GR-TR partners
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data	WINGS, COSMOTE, TURKCELL, ICCS	Pass	It has to be tested while the application servers will have been placed on the edge servers. GR edge server done.
External servers/ ITS Centers				
S5	Synchronisation measures are used for the server	All partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners
Other end-user devices (e.g. VRUs, smartphones)				
E1	Other end-user devices, which are needed for the user story, are available	ICCS	Pass	ICCS provides the application devices and is responsible for their transfer at the trial site. Devices have been tested for their function.
E2	End-user devices are connected to the network	ICCS	Pass	Application's network interface with the 5G network of COSMOTE was tested.
E3	The end-user devices have live connection to MEC over 4G/5G connectivity	WINGS, COSMOTE, TURKCELL, ICCS	Pass	Some last integration tests with the trucks the expected.
E4	The application algorithms on the end-user device are installed correctly and work as expected	ICCS	Pass	The applications algorithms have been installed and have been checked for their correct function in the lab and the necessary testbed. Latency issues have also been initially checked.
E5	The end-user devices are capable to transmit the relevant (C-ITS) messages according to the relevant standard and encoding	ICCS	Pass	H.264 /H.265 encoding. Encoded video frames are sent into RTP packets. These packets are sent over User Datagram Protocol (UDP) to a remote UDP sink. It has been tested in the lab and a 5G testbed

ID	Issue	Partner(s)	Result	Explanation
E6	Synchronisation measures are used for the server	All partners	Pass	Network Protocol Time is used to the SWIS application level. It has been tested in the lab and a 5G network testbed. Further tests will take place in the trial site. Specific UTP Servers have been identified and used for all GR-TR partners
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	COSMOTE, WINGS, TURKCELL, ICCS	Pass	
N3	MEC applications can handle the relevant C-ITS messages	WINGS, TURKCELL	Pass	SWIS application server will be installed in both COSMOTE and TURKCELL edge servers. COSMOTE edge server verified.
N4	The complete test area is covered by the 5G-networks	COSMOTE, TURKCELL	Pass	Each MNO has performed driving tests with specific driving test UEs & tools in order to verify the 5G network coverage offered by each MNO's gNBs at the test area.
N5	MEC access is provided for the whole test area	COSMOTE, TURKCELL	Pass	
N6	All MEC applications and data logging are synchronised	WINGS, COSMOTE, TURKCELL, ICCS	Pass	The application residing at the GR-TR_edge_02, and the OBU, UEs and RSI used for this US are all using the same NTP servers as the synch source. Each of these elements produces its own log file using the NTP acquired timing. Logs have been cross-checked and verified. For the SWIS app, data logging has been confirmed and checked in the application function level.
N7	Data is exchanged between MECs through agreed protocols	WINGS, TURKCELL	Pass	SWIS app works under agreed protocols supported by the project infrastructure
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	COSMOTE, TURKCELL	Not relevant	Due to COVID-19 travel restrictions, it was not feasible to perform handover test & logging at the specific handover point of the test area. However, both MNOs and Ericsson (GR & TR) have identified an alternative option to perform the handover at each MNO's territory (via changing handover parameters) and validate the e2e handover procedure from both sides. Network configuration to be commonly agreed. In parallel, both MNOs and Ericsson (GR & TR) currently perform ping tests (using routable IP addresses) to validate core-to-core network integration, prior to leased line availability, for both LBO & Home Routed architecture options (S6a, S8 & S10 cross-network interfaces connectivity).

ID	Issue	Partner(s)	Result	Explanation
N10	MEC1 can connect with MEC2 and vice-versa	COSMOTE, TURKCELL	Not relevant	Edge nodes (located at Alexandroupoli (MEC2, GR) & Istanbul (MEC1, TR)) connect to the edge DCs (at Alexandroupoli (GR) & Istanbul (TR), respectively), where the overlay vEPC functionalities are deployed, while the 5G UE – application servers' connectivity is provided over the PGW SGi interface. Thus, in order to validate connectivity between MECs, the validation of cross-core network integration is required, which is ongoing, as described above.
N11	The UEs can roam between MNO1 and MNO2		Pass	GR UEs are ok with that requirement. Waiting for the TR edge server's availability this has notn been verified for the TR UEs. However, it does not affect the application's performance and the necessary outcome as the LBO tests will take place with only the GR UEs (COSMOTE sim cards).
Privacy and security issues				
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	All partners	Pass	GDPR issues are currently addressed for their timely solution.
Logging related issues				
L1	Logging is in place for all components	All partners	Pass	For the SWIS application, application server and devices include a logging module for the application's performance measurement. It has been tested on a lab environment and a local 5G testbed. DEKRA tools will be used to monitor the bandwidth and the upstream and downstream of the application, along with the possibility of detecting packet drop.
L2	Procedures for starting logging are in place	All partners	Pass	Measurement of the E2E latency of the UDP control commands is based on the unique identifier of each command and a time stamp at the moment of being issued towards the respective module of the architecture. It has been taken into consideration during the application design.
L3	Logging formats comply with the agreed format	All partners	Pass	A predefined data format is applied. The common Data Format is used for logging.
L4	Logged data can be uploaded to the CTS	All partners	Pass	It will be tested in the trial site.
L5	All data required is logged	All partners	Pass	For the SWIS app, all data required for application's performance is logged.
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	All partners	Pass	It will be tested in the trial site.

6.2.2 US#2.1.b: Platooning through 5G Connectivity (GR-TR)

Table 53: Checklist of the Platooning through 5G Connectivity user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	FORD	Pass	Equipment installed to the vehicles.
V2	The physical components are integrated and operate correctly	FORD, IMEC	Pass	Physical components integration with the vehicle is currently in progress.
V3	The physical components, integrated in the vehicle, send the correct information	FORD, IMEC	Pass	Physical components integration with the vehicle is currently in progress.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	FORD, TURKCELL, IMEC	Partly	After readiness off second vehicle and MQTT client, tests will be initiated. Vehicle relevant applications has been tested with DSRC communication previously.
V5	The vehicle applications are correctly installed	FORD	Partly	The application installed on the vehicle but it is not ready yet.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	FORD	Pass	After readiness off second vehicle and MQTT client, tests will be initiated. Vehicle relevant applications has been tested with DSRC communication previously.
V7	Messages and data content and encoding have been agreed between partners.	FORD, IMEC	Pass	Agreed.
V8	The vehicle has safety measures in place to allow the driver to take control	FORD	Pass	The driver can take over control from the automated vehicle in critical situations with braking or steering the wheel.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	All GR-TR partners	Pass	All the necessary permissions have been given for the tests.
OBU related issues				
V10	All OBUs are ready and available for the trials	IMEC	Pass	IMEC provides the OBUs and currently are at Ford for the integration with their vehicles
V11	The OBUs are correctly installed in the CAV/CV	FORD, IMEC	Pass	Integration with vehicle is in progress. Bench integration that imitates vehicle is completed.
V12	The applications in the OBU behave as expected and are validated	IMEC	Pass	IMEC has tested the OBU before sending it to the Turkey.

ID	Issue	Partner(s)	Result	Explanation
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	Not part of the OBU specifications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity		Not relevant	No MEC implementation in this US.
V15	The OBUs connect and have access to the 5G network	IMEC, Turkcell	Pass	Turkcell has tested the OBUs in İstanbul.
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	IMEC	Pass	OBU connectivity to TURKCELL PLATOONING CLOUD is not tested yet.
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	FORD, IMEC	Not tested	Required components implementation in progress.
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	Another component is used for positioning.
V19	Synchronisation measures are used for the OBU	All GR-TR partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners.
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	TURKCELL, IMEC	Partly	OBU MQTT Client is not ready yet.
S2	External servers are connected to the network and accessible by all partners needing access	TURKCELL	Pass	
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	TURKCELL	Not tested	
S4	Messages with the servers can be exchanged according to the relevant specifications	TURKCELL	Partly	
S5	Synchronisation measures are used for the server	All GR-TR partners	Pass	
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications		Not relevant	No MEC implementation in this US.

ID	Issue	Partner(s)	Result	Explanation
N2	All partners have access to the needed interfaces and infrastructure	FORD, IMEC, TUBITAK, Turkcell	Not tested	
N4	The complete test area is covered by the 5G-networks	Turkcell	Pass	
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Not tested	
N11	The UEs can roam between MNO1 and MNO2		Not tested	
Privacy and security issues				
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	FORD, TUBITAK, IMEC	Not relevant	All data will be exchanged anonymously.
Logging related issues				
L1	Logging is in place for all components	FORD	Pass	As soon as test is started operator will start logging on PC that is located in vehicle and start logging vehicle controller messages.
L2	Procedures for starting logging are in place	FORD	Pass	Related messages will be logged at the PCs in the vehicle that are connected to MicroAutoBox unit.
L3	Logging formats comply with the agreed format	TURKCELL	Not tested	MQTT logging will be tested.
L4	Logged data can be uploaded to the CTS	TURKCELL	Not tested	MQTT logging will be tested.
L5	All data required is logged	TURKCELL, FORD	Not tested	MQTT logging will be tested.
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	All GR-TR partners	Not tested	

6.2.3 US#2.2: eRSU-Assisted Platooning (DE)

Table 54: Checklist of the eRSU Assisted Platooning user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials		Pass	Vehicles are in place and have been reserved by the partners to be utilized in the trialing days
V2	The physical components are integrated and operate correctly		Pass	All components operating within parameters. Verified in early trials 24-25 of march
V3	The physical components, integrated in the vehicle, send the correct information		Pass	All components operating within parameters. Verified in early trials 24-25 of march
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated		Pass	Platooning messages can be sent and received via PC5 interface but the correct performance of the application still needs to be verified
V5	The vehicle applications are correctly installed		Pass	The applications are correctly installed in the onboard computer.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.		Pass	OBU measurements are provided to the application
V7	Messages and data content and encoding have been agreed between partners.		Pass	Platooning custom messages have been implemented and are agreed between the partners. (CPM, PCM, PMM, CAM_v2)
V8	The vehicle has safety measures in place to allow the driver to take control		Not relevant	Platooning use case is simulated and has no automated functions, only instructions to driver
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received		Not relevant	No permits needed for this use case
OBU related issues				
V10	All OBUs are ready and available for the trials		Pass	TUB OBUs from Cohda Wireless are available in trial site and have been tested by sending ITS messages. Valeo Peiker OBU successfully connected to 5G network in the vehicle
V11	The OBUs are correctly installed in the CAV/CV		Pass	Cohda OBU installed in both vehicles and test verified

ID	Issue	Partner(s)	Result	Explanation
V12	The applications in the OBU behave as expected and are validated		Pass	Platooning messages can be sent and received via PC5 interface but the correct performance of the application still needs to be verified
V13	The OBUs can manage and run 3rd party CCAM applications		Pass	The OBU is based on Linux and can host any kind of native application developed, not only CCAM but any regular application
V14	The OBUs have a live connection to MEC over 4G/5G connectivity		Pass	Ping to IP addresses of MEC servers deployed in DT and TUB infrastructures has been successfully performed
V15	The OBUs connect and have access to the 5G network		Pass	TCU have been tested with Telekom's NSA network along the TS
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding		Pass	Cohda OBUs have been tested sending and receiving CPM, PCM, DENM and CAM messages.
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)		Pass	OBUs receiving messages relevant for its area thanks to the Geobroker in the MEC
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	GNSS used for positioning
V19	Synchronisation measures are used for the OBU		Pass	GNSS clock used for synchronization of the local clocks using a local NTP server
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured		Pass	Object detection messages, generated with cameras of the TUB infrastructure have been correctly received in the OBUs
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity		Not relevant	Cameras connected to the TUB internal network
I3	The infrastructure sensors connect and have access to the 5G network		Not relevant	Cameras connected to the TUB internal network
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding		Pass	Object detection generated with cameras of the TUB infrastructure is codified in CPM messages and sent to the C-V2X network through the PC5 interface of the RSUs
I5	Synchronisation measures are used for the infrastructure		Pass	GNSS clock used for synchronization of the local clocks using a local NTP server

ID	Issue	Partner(s)	Result	Explanation
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data		Pass	Object detection generated with cameras of the TUB infrastructure is codified in CPM messages and sent to the C-V2X network through the PC5 interface of the RSUs
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available		Pass	Kafka Server providing object detection information has been tested . Vehicle Discovery Server is deployed and working
S2	External servers are connected to the network and accessible by all partners needing access		Pass	Object detection messages received from the server.
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated		Pass	Object detection messages received from the server.
S4	Messages with the servers can be exchanged according to the relevant specifications		Pass	Object detection messages received from the server.
S5	Synchronisation measures are used for the server		Not relevant	GNSS clock used for synchronization of the local clocks using a local NTP server
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications		Pass	The OBU is based on Linux and can host any kind of native application developed, not only CCAM but any regular application
N2	All partners have access to the needed interfaces and infrastructure		Pass	Vehicles are receiving broadcasted messages from the eRSU (far edge MEC) and video streaming from the Servers (near Edge MEC)
N3	MEC applications can handle the relevant C-ITS messages		Pass	MEC deployed with eRSU, correctly sending CPM messages
N4	The complete test area is covered by the 5G-networks		Pass	In both sides of the emulated border 5G coverage has been validated.
N5	MEC access is provided for the whole test area		Pass	MEC access available via 5G
N6	All MEC applications and data logging are synchronised		Pass	GNSS clock used for synchronization of the local clocks using a local NTP server
N7	Data is exchanged between MECs through agreed protocols		Pass	Data exchanged between MECs via MQTT messages
N8	The algorithms for geolocation and filtering of messages work as expected		Pass	Geobroker filtering and forwarding only relevant messages for the vehicle in its driving direction

ID	Issue	Partner(s)	Result	Explanation
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Not relevant	Different Networks SA & NSA will be overlapped and depending on Geo-position where a virtual border will trigger the roaming from a network and MEC utilization perspective, managing the MEC interconnection and session roaming from one infrastructure to another one trying to minimise the impact on CCAM application
N10	MEC1 can connect with MEC2 and vice-versa		Pass	MEC interconnection has been validated. MQTT messages exchange between both MECs
N11	The UEs can roam between MNO1 and MNO2		Pass	Switch communication path from one modem to the other
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…		Not relevant	Security needs to be deactivated to allow production of measurements
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Not relevant	Security needs to be deactivated to allow production of measurements
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)		Pass	Geonetworking and MQTT
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Pass	CPM messages only containing information relevant to objects in the road, no personal information stored or reproduced
Logging related issues				
L1	Logging is in place for all components		Pass	Components are logging data when they start running
L2	Procedures for starting logging are in place		Pass	Components are logging data when they start running
L3	Logging formats comply with the agreed format		Pass	Data collection using CDF definitions
L4	Logged data can be uploaded to the CTS		Pass	Pre integration workshop for CTS tested in march
L5	All data required is logged		Pass	Measurements collected and stored in common data format.

ID	Issue	Partner(s)	Result	Explanation
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	All devices are synchronized with GPS clock

6.2.4 US#2.3: Cloud-Assisted Platooning (CN)

Table 55: Checklist of the Cloud-Assisted Platooning user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	CNHTC	Pass	CN_veh_03 was ready with OBU, and CN_veh_04 was ready
V2	The physical components are integrated and operate correctly	CNHTC, DATANG	Pass	Physical components integration with CN_veh_04 was ready
V3	The physical components, integrated in the vehicle, send the correct information	CNHTC, DATANG	Pass	Physical components integration with CN_veh_04 is currently in progress
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CNHTC, DATANG, DUT	Pass	The vehicle applications are ready.
V5	The vehicle applications are correctly installed	CNHTC, DATANG, DUT	Pass	The installation of vehicle applications are ready.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	CNHTC, DUT	Pass	Integration has completed.
V7	Messages and data content and encoding have been agreed between partners.	CNHTC, DUT	Pass	Agreed
V8	The vehicle has safety measures in place to allow the driver to take control	CNHTC	Pass	The drivers can take over control from the automated vehicle in critical situations with braking or steering the wheel
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	All CN partners	Pass	All the necessary permissions have been given for the tests.

ID	Issue	Partner(s)	Result	Explanation
OBU related issues				
V10	All OBUs are ready and available for the trials	DATANG	Pass	DATANG provides the OBUs and currently are at CNHTC for the integration with their vehicles
V11	The OBUs are correctly installed in the CAV/CV	DATANG, CNHTC	Pass	Integration with vehicle is ready.
V12	The applications in the OBU behave as expected and are validated	DATANG, CNHTC	Pass	DATANG has tested the OBU before sending it to the CNHTC
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	Not part the OBU specifications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity		Not relevant	MEC is not available in this US
V15	The OBUs connect and have access to the 5G network	DATANG, CNHTC	Pass	DATANG has tested 5G connection of the OBU in Shanghai city
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	DATANG, DUT	Pass	5G OBU connectivity in this US is ready
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	CNHTC, DUT	Pass	Geolocation messaging components implementation has been completed.
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	BeiDou component is employed for positioning.
V19	Synchronisation measures are used for the OBU	All CN partners	Pass	A confirmed NTP server is used for all CN partners
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	CNHTC, DUT	Partly	MQTT Client on OBU is not tested.
S2	External servers are connected to the network and accessible by all partners needing access	SDHS	Pass	SDHS has tested the connection and accessibility of the servers
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	SDHS	Pass	Required components is ready

ID	Issue	Partner(s)	Result	Explanation
S4	Messages with the servers can be exchanged according to the relevant specifications	SDHS, DUT, CNHTC	Pass	Required components is available
S5	Synchronisation measures are used for the server	All CN partners	Pass	
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	All CN partners	Pass	
N4	The complete test area is covered by the 5G-networks	SDHS	Pass	
N11	The UEs can roam between MNO1 and MNO2	DATANG	Pass	
Privacy and security issues				
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	All CN partners	Partly	Required components are not ready
Logging related issues				
L1	Logging is in place for all components	DUT, SDHS	Pass	logging in on-board computer of vehicle and cloud server for controller message has been tested.
L2	Procedures for starting logging are in place	DUT, SDHS	Pass	Related messages will be logged at the onboard computer in the vehicle
L3	Logging formats comply with the agreed format	DUT, SDHS	Pass	Required components are ready
L4	Logged data can be uploaded to the CTS	DUT, SDHS	Pass	Required components are ready
L5	All data required is logged	DUT, SDHS	Pass	Required components are ready
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	All CN partners	Partly	Required components are not ready

6.3 Extended Sensors

6.3.1 US#3.1.a: Complex Manoeuvres in Cross-Border Settings: HD Maps (ES-PT)

Table 56: End-user devices in the HD Maps user story in the ES-PT CBC

UE ID	Type of UE	UE host ID	UE host description
ES-PT_UE_01	OBU	ES-PT_veh_01	Citroën C4, autonomous
ES-PT_UE_03	OBU	ES-PT_veh_03	Volkswagen Golf, autonomous
ES-PT_UE_06	OBU	ES-PT_veh_06	PT Connected Vehicle

Table 57: MECs in the HD Maps user story in the ES-PT CBC

MEC/Server ID	Country	MNO ID	MEC Server Name
ES-PT_MEC_01	ES	ES-PT_MNO_02	MEC Calvario CT
ES-PT_MEC_02	PT	ES-PT_MNO_03	MEC Riba d'Ave
ES-PT_serv_01	ES	ES-PT_MNO_02	ES ITS Centre
ES-PT_serv_02	PT	ES-PT_MNO_03	PT ITS Centre

Table 58: Applications in the HD Maps user story in the ES-PT CBC

Application ID	Description	Installed in
ES-PT_veh_app_01	MQTT client	ES-PT_veh_01 ES-PT_veh_03 ES-PT_veh_06
ES-PT_veh_app_02	app for collecting and sending sensors information	ES-PT_veh_01
ES-PT_veh_app_03	app for receiving the updated HDMaps	ES-PT_veh_03
ES-PT_veh_app_04	app for receiving the updated information extracted from sensors (JSON)	ES-PT_veh_06
ES-PT_veh_app_05	app for managing the info to perform the autonomous function	ES-PT_veh_03
ES-PT_MEC_app_01	MQTT server	ES-PT_MEC_01 ES-PT_MEC_02
ES-PT_serv_app_01	HDMaps module to dump the sensors information into the database	ES-PT_serv_01 ES-PT_serv_02

Table 59: Checklist of the HD Maps user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	CTAG AtoBe IT	Pass	ES-PT_veh_01, ES-PT_veh_03 and ES-PT_veh_06 have 5G connectivity and the required CCAM functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_01 (only for monitorization activities in this US) is installed in ES-PT_veh_01, ES-PT_veh_03 and ES-PT_veh_06 and is ready for the tests 2) ES-PT_veh_app_02 is installed in ES-PT_veh_01 and is ready for the tests 3) ES-PT_veh_app_03 and ES-PT_veh_app_05 are installed in ES-PT_veh_03 and are ready for the tests 4) ES-PT_veh_app_04 is installed in ES-PT_veh_06 and is ready for the tests
V3	The physical components, integrated in the vehicle, send the correct information	CTAG	Pass	ES-PT_veh_app_02: the lidar (road boundary detection) and the camera (traffic sign recognition) are dumping the object detection information to the CAN bus. It is checked by means of specific software (Canalyzer) and also visualized in the HMI
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_02: ES-PT_veh_01 is sending a large file with sensors information, verified by visual examination of the reception of this file in ES-PT_serv_01 2) ES-PT_veh_app_03: ES-PT_serv_01 is sending the updated HDMaps, verified by visual examination of the file received by ES-PT_veh_03 3) ES-PT_veh_03 is accessing all the required information via CAN to be able to perform the autonomous function 3) ES-PT_veh_app_04 receives and displays CAM, DENM and HD Maps JSON updates and is ready for the tests
V5	The vehicle applications are correctly installed	CTAG AtoBe IT	Pass	The same as V4

ID	Issue	Partner(s)	Result	Explanation
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_01 has access to the CAN bus to get the GPS data to create the CAM messages 2) ES-PT_veh_app_02 has access to camera and lidar records to send the file with sensor information 3) ES-PT_veh_app_03 has access to the HDMaps in ES-PT_veh_03 to replace the existing one 4) ES-PT_veh_app_04 has access to the messages from ES-PT_UE_06. The actual ES-PT_UE_06 has access to these messages from the MEC broker.
V7	Messages and data content and encoding have been agreed between partners.	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_01 is publishing/subscribing in the MEC (only for monitorization activities, no impact on the US working): - CAM - ETSI EN 302 637-2 V1.4.1 2) ES-PT_veh_app_02 and ES-PT_veh_app_03 are using propietary formats
V8	The vehicle has safety measures in place to allow the driver to take control	CTAG	Pass	Changing from autonomous driving to manual driving Pressing brake pedal Steering wheel torque over 6Nm Pushing the emergency button
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	CTAG AtoBe IT	Pass	The national traffic authorities in ES and PT have provided time slots to perform the final tests in open road but the verification tests are performed in a controlled environment for safety reasons
OBU related issues				
V10	All OBUs are ready and available for the trials	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are provided by CTAG 2) ES-PT_UE_06 is provided by IT
V11	The OBUs are correctly installed in the CAV/CV	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are located in the trunk, connected to the power supply of the vehicles using "banana plugs". The modem is connected to an antenna on the roof of the vehicle. 2) ES-PT_UE_06 is portable and is only installed in ES-PT_veh_06 when tests need to be run through a simple process (lighter power and exterior antennas connection only)
V12	The applications in the OBU behave as expected and are validated	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_03 are checked by means of a SSH connection to check that all the processes are running 2) ES-PT_UE_06 is checked by means of a SSH connection to check that all the processes are running
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	No 3rd party CCAM applications

ID	Issue	Partner(s)	Result	Explanation
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	CTAG IT Nokia ES Nokia PT	Pass	Checked by a ping from from ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 to ES-PT_MEC_01 and ES-PT_MEC_02
V15	The OBUs connect and have access to the 5G network	CTAG IT Telefónica NOS	Pass	ES-PT_UE_01, ES_PT_UE_03 and ES-PT_UE_06: checked by accessing radio parameters of the modem and identifying ES-PT_MNO_02 and ES-PT_MNO_03 and the 5G bands
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG IT Nokia ES Nokia PT	Pass	ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 are publishing and receiving messages to the ES-PT_ MEC_01 and ES-PT_MEC_02 (verified by means of the application and network logs)
V19	Synchronisation measures are used for the OBU	CTAG IT Nokia ES Nokia PT	Pass	ES-PT_UE_01, ES-PT_UE_03 and ES-PT_UE_06 are publishing and receiving messages to/from the ES-PT_ MEC_01/ES-PT_MEC_02 in its cell and adjacent ones
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	CTAG InfraPT AtoBe	Pass	1) ES-PT_serv_01 is provided by CTAG 2) ES-PT_serv_02 is provided by InfraPT
S2	External servers are connected to the network and accessible by all partners needing access	CTAG InfraPT AtoBe	Pass	1) ES-PT_veh_01 uploads sensor file to ES-PT_serv_01/ES-PT_serv_02 and ES-PT_serv_01/ES-PT_serv_02 disseminates updated HDMaps to ES-PT_veh_03, checked by visual inspection of the files in OBUs and server. 2) ES-PT_serv_01/ES-PT_serv_02 disseminates updated JSON file to ES-PT_veh_06 through the MEC broker
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	CTAG AtoBe	Pass	The same as S2
S4	Messages with the servers can be exchanged according to the relevant specifications	CTAG AtoBe	Pass	ES-PT_serv_01/ES-PT_serv_02 disseminates DENM with the Road Works through the MEC broker
S5	Synchronisation measures are used for the server	CTAG AtoBe	Pass	ES-PT_serv_01/ES-PT_serv_02 has implemented synchronization using NTP

ID	Issue	Partner(s)	Result	Explanation
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	CTAG IT Nokia ES Nokia PT	Pass	ES-PT_MEC_app_01 in ES-PT_MEC_01 and ES-PT_MEC_02 is publishing / subscribing CAM messages from / to ES-PT_UE_01 (ES-PT_veh_app_01), ES-PT_UE_03 (ES-PT_veh_app_01) and ES-PT_UE_06 (ES-PT_veh_app_01)
N2	All partners have access to the needed interfaces and infrastructure	CTAG IT Nokia ES Nokia PT	Pass	The same as N1
N3	MEC applications can handle the relevant C-ITS messages	CTAG IT Nokia ES Nokia PT	Pass	The same as N1
N4	The complete test area is covered by the 5G-networks	Telefonica NOS Nokia ES Nokia PT	Pass	Tested with a coverage map
N5	MEC access is provided for the whole test area	Telefonica NOS Nokia ES Nokia PT	Pass	Tested running the ES-PT_MEC_app_01 and ES-PT_UE_app_01
N6	All MEC applications and data logging are synchronised	Telefonica NOS Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 have implemented synchronization using NTP
N7	Data is exchanged between MECs through agreed protocols	CTAG IT	Pass	- CAM - ETSI EN 302 637-2 V1.4.1
N8	The algorithms for geolocation and filtering of messages work as expected	CTAG	Pass	Tested and working as expected with zoom 18 in the MECs and publishing/subscribing to the own and the neighbouring cells
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests satisfactory by using the OBUs with US data

ID	Issue	Partner(s)	Result	Explanation
N10	MEC1 can connect with MEC2 and vice-versa	Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 interchanges ETSI C-ITS messages
N11	The UEs can roam between MNO1 and MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests with home routed already executed satisfactorily in both directions (ES-PT and PT-ES)
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	CTAG IT Nokia ES Nokia PT	Pass	1) ES-PT_MEC_01 and ES-PT_MEC_02 are VPN 2) ES-PT_MEC_app_01 is a MQTT over TLS 3) ES-PT_serv_app_01 is sFTP
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Not relevant	There is no certificate exchange for C-ITS messages. Access to network is granted through provisioning SIM cards.
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)		Not relevant	No ETSI ITS geonet headers are used, just ITS messages payload protected by MQTT over TLS. Interoperability is being tested at this time.
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Not relevant	There is no storage of such data.
Logging related issues				
L1	Logging is in place for all components	CTAG IT AtoBe	Pass	TFT3.1.1-CAM: CAM messages between connected vehicles and MEC - ES-PT_veh_01, ES-PT_veh_03 and ES-PT_veh_06: CAM messages sent and received - ES-PT_MEC_01 and ES-PT_MEC_02: CAM messages published TFT3.1.2-Sensors Data: raw data from in-vehicle sensors to ITS Centre - ES-PT_veh_01: sensor file sent - ES-PT_serv_01: sensor file received - ES-PT_serv_02 is not yet ready for the tests TFT3.1.3-Updated HDMaps: updated HDMaps from ITS Centre to host vehicle - ES-PT_serv_01: HDMaps sent - ES-PT_serv_02 is not yet ready for the tests - ES-PT_veh_03 and ES-PT_veh_06: HDMaps received

ID	Issue	Partner(s)	Result	Explanation
L2	Procedures for starting logging are in place		Not relevant	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format	CTAG IT	Pass	The tools to convert the raw data into the common data format are developed
L4	Logged data can be uploaded to the CTS	CTAG IT	Pass	First test with no evaluation data already upload to validate the process
L5	All data required is logged	CTAG IT AtoBe	Pass	1) ES-PT_veh_01, ES-PT_veh_03, ES-PT_veh_06 are logging as expected 2) ES_PT_serv_01 and ES-PT_serv_02 are logging as expected
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	CTAG IT AtoBe	Pass	1) ES-PT_veh_01, ES_PT_veh_03 and ES-PT_veh_06 are synchronized 2) ES-PT_serv_01 and ES_PT_serv_02 are synchronized

6.3.2 US#3.1.b: Public Transport: HD Maps

Table 60: End-user devices in the Public transport user story in the ES-PT CBC

UE ID	Type of UE	UE host ID	UE host description
ES-PT_UE_03	OBU	ES-PT_veh_03	Volkswagen Golf, autonomous
ES-PT_UE_05	OBU	ES-PT_veh_05	ALSA connected bus
ES-PT_UE_06	OBU	ES-PT_veh_06	PT Connected Vehicle

Table 61: MECs in the Public transport user story in the ES-PT CBC

MEC/Server ID	Country	MNO ID	MEC Server Name
ES-PT_MEC_01	ES	ES-PT_MNO_02	MEC Calvario CT
ES-PT_MEC_02	PT	ES-PT_MNO_03	MEC Riba d'Ave
ES-PT_serv_01	ES	ES-PT_MNO_02	ES ITS Centre
ES-PT_serv_02	PT	ES-PT_MNO_03	PT ITS Centre

Table 62: Applications in the Public transport user story in the ES-PT CBC

Application ID	Description	Installed in
ES-PT_veh_app_01	MQTT client	ES-PT_veh_03 ES-PT_veh_05 ES-PT_veh_06
ES-PT_veh_app_02	app for collecting and sending sensors informatio	ES-PT_veh_05
ES-PT_veh_app_03	app for receiving the updated HDMaps	ES-PT_veh_03
ES-PT_veh_app_04	app for receiving the updated information extracted from sensors (JSON)	ES-PT_veh_06
ES-PT_veh_app_05	app for managing the info to perform the autonomous function	ES-PT_veh_03
ES-PT_MEC_app_01	MQTT server	ES-PT_MEC_01 ES-PT_MEC_02
ES-PT_serv_app_01	HDMaps module to dump the sensors information into the database	ES-PT_serv_01 ES-PT_serv_02

Table 63: Checklist for the Public Transport HD Maps user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	CTAG ALSA AtoBe, IT	Pass	ES-PT_veh_3, ES-PT_veh_05 and ES-PT_veh_06 have 5G connectivity and the required CCAM functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG AtoBe	Pass	1) ES-PT_veh_app_01 (only for monitorization activities in this US) is installed in ES-PT_veh_03, ES-PT_veh_05 and ES-PT_veh_06 and it is ready for the tests 2) ES-PT_veh_app_02 is installed in ES-PT_veh_05 and ready for the tests 3) ES-PT_veh_app_03 and ES-PT_veh_app_05 are installed in ES-PT_veh_03 and are ready for the tests 4) ES-PT_veh_app_04 is installed in ES-PT_veh_06 and is ready for the tests
V3	The physical components, integrated in the vehicle, send the correct information	CTAG	Pass	ES-PT_veh_app_02: the lidar (road boundary detection) and the camera (traffic sign recognition) are dumping the object detection information to the CAN bus. It is checked by means of specific software (Canalyzer) and also visualized in the HMI

ID	Issue	Partner(s)	Result	Explanation
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG AtoBe	Pass	1) ES-PT_veh_app_02: ES-PT_veh_05 is sending a large file with sensors information, verified by visual examination of the reception of this file in ES-PT_serv_01 2) ES-PT_veh_app_03: ES-PT_serv_01 is sending the updated HDMaps, verified by visual examination of the file received by ES-PT_veh_03 3) ES-PT_veh_03 is accessing all the required information via CAN to be able to perform the autonomous function 3) ES-PT_veh_app_04 receives and displays CAM, CPM, DENM and HD Maps JSON updates and is ready for the tests
V5	The vehicle applications are correctly installed	CTAG AtoBe	Pass	The same as V4
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	CTAG AtoBe	Pass	1) ES-PT_veh_app_01 has access to the CAN bus to get the GPS data to create the CAM messages 2) ES-PT_veh_app_02 has access to camera and lidar records to send the file with sensor information 3) ES-PT_veh_app_03 has access to the HDMaps in ES-PT_veh_03 to replace the existing one 4) ES-PT_veh_app_04 has access to the messages from the OBU ES-PT_UE_06. The actual OBU ES-PT_UE_06 has access to these messages from the MEC broker.
V7	Messages and data content and encoding has been agreed between partners.	CTAG AtoBe IT	Pass	1) ES-PT_veh_app_01 is publishing/subscribing in the MEC (only for monitorization activities, no impact on the US working): - CAM - ETSI EN 302 637-2 V1.4.1 2) ES-PT_veh_app_02 and ES-PT_veh_app_03 are using propietary formats
V8	The vehicle has safety measures in place to allow the driver to take control	CTAG	Pass	Changing from autonomous driving to manual driving Pressing brake pedal Steering wheel torque over 6Nm Pushing the emergency button
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	CTAG AtoBe IT	Pass	The national traffic authorities in ES and PT have provided time slots to perform the final tests in open road but the verification tests are performed in a controlled environment for safety reasons
OBU related issues				
V10	All OBUs are ready and available for the trials	CTAG IT	Pass	1) ES-PT_UE_01 and ES-PT_UE_05 are provided by CTAG 2) ES-PT_UE_06 is provided by IT

ID	Issue	Partner(s)	Result	Explanation
V11	The OBUs are correctly installed in the CAV/CV	CTAG IT	Pass	1) ES-PT_UE_01 is located in the trunk and ES_PT_UE_05 in a compartment close to the driver, connected to the power supply of the vehicles using "banana plugs". The modem is connected to an antenna on the roof of the vehicle.. 2) ES-PT_UE_06 is portable and is only installed in ES-PT_veh_06 when tests need to be run through a simple process (lighter power and exterior antennas connection only)
V12	The applications in the OBU behave as expected and are validated	CTAG IT	Pass	1) ES-PT_UE_03 and ES-PT_UE_05 are checked by means of a SSH connection to check that all the processes are running 2) ES-PT_UE_06 is checked by means of a SSH connection to check that all the processes are running
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	No 3rd party CCAM applications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	CTAG, IT Nokia ES Nokia PT	Pass	Checked by a ping from ES-PT_UE_03, ES-PT_UE_05 and ES-PT_UE_06 to ES-PT_MEC_01 and ES-PT_MEC_02
V15	The OBUs connect and have access to the 5G network	CTAG, IT Telefónica NOS	Pass	ES-PT_UE_03, ES_PT_UE_05 and ES-PT_UE_06: checked by accessing radio parameters of the modem and identifying ES-PT_MNO_02 and ES-PT_MNO_03 and the 5G bands
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG, IT Nokia ES Nokia PT	Pass	ES-PT_UE_03, ES-PT_UE_05 and ES-PT_UE_06 are publishing and receiving messages to the ES-PT_ MEC_01 and ES-PT_MEC_02 (verified by means of the application and network logs)
V19	Synchronisation measures are used for the OBU	CTAG, IT Nokia ES Nokia PT	Pass	ES-PT_UE_03, ES-PT_UE_05 and ES-PT_UE_06 are publishing and receiving messages to/from the ES-PT_ MEC_01/ES-PT_MEC_02 in its cell and adjacent ones
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	CTAG InfraPT AtoBe	Pass	1) ES-PT_serv_01 is provided by CTAG 2) ES-PT_serv_02 is provided by InfraPT
S2	External servers are connected to the network and accessible by all partners needing access	CTAG InfraPT AtoBe	Pass	1) ES-PT_veh_05 uploads sensor file to ES-PT_serv_01/ES-PT_serv_02 and ES-PT_serv_01/ES-PT_serv_02 disseminates updated HDMaps to ES-PT_veh_03, checked by visual inspection of the files in OBUs and server. 2) ES-PT_serv_01/ES-PT_serv_02 disseminates updated JSON file to ES-PT_veh_06 through the MEC broker

ID	Issue	Partner(s)	Result	Explanation
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	CTAG IT AtoBe	Pass	The same as S2
S4	Messages with the servers can be exchanged according to the relevant specifications		Pass	ES-PT_serv_01/ES-PT_serv_02 disseminates DENM with the Road Works through the MEC broker
S5	Synchronisation measures are used for the server	CTAG IT	Pass	ES-PT_serv_01/ES-PT_serv_02 has implemented synchronization using NTP
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	CTAG, IT Nokia ES Nokia PT	Pass	ES-PT_MEC_app_01 in ES-PT_MEC_01 and ES-PT_MEC_02 is publishing / subscribing CAM messages from / to ES-PT_UE_01 (ES-PT_veh_app_01), ES-PT_UE_03 (ES-PT_veh_app_01) and ES-PT_UE_06 (ES-PT_veh_app_01)
N2	All partners have access to the needed interfaces and infrastructure	CTAG, IT Nokia ES Nokia PT	Pass	The same as N1
N3	MEC applications can handle the relevant C-ITS messages	CTAG, IT Nokia ES Nokia PT	Pass	The same as N1
N4	The complete test area is covered by the 5G-networks	Telefonica NOS Nokia ES Nokia PT	Pass	Tested with a coverage map
N5	MEC access is provided for the whole test area	Telefonica NOS Nokia ES Nokia PT	Pass	Tested running the ES-PT_MEC_app_01 and ES-PT_UE_app_01
N6	All MEC applications and data logging are synchronised	Telefonica NOS Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 have implemented synchronization using NTP
N7	Data is exchanged between MECs through agreed protocols	CTAG IT	Pass	- CAM - ETSI EN 302 637-2 V1.4.1
N8	The algorithms for geolocation and filtering of messages work as expected	CTAG	Pass	Tested and working as expected with zoom 18 in the MECs and publishing/subscribing to the own and the neighbouring cells

ID	Issue	Partner(s)	Result	Explanation
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests satisfactory by using the OBUs with US data
N10	MEC1 can connect with MEC2 and vice-versa	Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 interchanges ETSI C-ITS messages
N11	The UEs can roam between MNO1 and MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests with home routed already executed satisfactorily in both directions (ES-PT and PT-ES)
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	CTAG, IT Nokia ES Nokia PT	Pass	1) ES-PT_MEC_01 and ES-PT_MEC_02 are VPN 2) ES-PT_MEC_app_01 is a MQTT over TLS 3) ES-PT_serv_app_01 is sFTP
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Not relevant	There is no certificate exchange for C-ITS messages. Access to network is granted through provisioning SIM cards.
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Not relevant	There is no storage of such data.

ID	Issue	Partner(s)	Result	Explanation
Logging related issues				
L1	Logging is in place for all components	ALSA CTAG IT	Pass	TFT3.1.1-CAM: CAM messages between connected vehicles and MEC - ES-PT_veh_03 and ES-PT_veh_05: CAM messages sent and received - ES-PT_MEC_01: CAM messages published - ES-PT_veh_06 and ES-PT_MEC 02 are not yet ready for the trials TFT3.1.2-Sensors Data: raw data from in-vehicle sensors to ITS Centre - ES-PT_veh_05: sensor file sent - ES-PT_serv_01: sensor file received - ES-PT_serv_02 is not yet ready for the tests TFT3.1.3-Updated HD Maps: updated HD Maps from ITS Centre to host vehicle - ES-PT_serv_01: HD Maps sent - ES-PT_serv_02 is not yet ready for the tests - ES-PT_veh_03: HD Maps received
L2	Procedures for starting logging are in place		Not relevant	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format	CTAG IT	Partly	The tools to convert the raw data into the common data format are being developed
L4	Logged data can be uploaded to the CTS		Not tested	The local server to be hosted at CTAG is not yet ready
L5	All data required is logged	CTAG IT	Partly	1) ES-PT_UE_03, ES-PT_UE_05 and ES_PT_serv_01 are logging as expected 2) ES-PT_veh_06 and ES-PT_MEC_02 are not logging
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	CTAG IT	Partly	1) ES-PT_UE_03, ES_PT_UE_05 and ES-PT_serv_01 are synchronized 2) ES-PT_UE_06 and ES-PT_serv_02 are not ready to be checked

6.3.3 US#3.2.a: Extended Sensors for Assisted Border-Crossing (GR-TR)

Table 64: Checklist for the Assisted Border Crossing user story (Advanced version)

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	FORD	Pass	

ID	Issue	Partner(s)	Result	Explanation
V2	The physical components are integrated and operate correctly	FORD, IMEC, WINGS	Pass	After integration, each one should test if the components (listed in US_data sheet) integrated are connected and start and if each of these components
V3	The physical components, integrated in the vehicle, sent the correct information	FORD, IMEC, WINGS	Pass	The correct operation has been verified with the remote integration tests. Another test will take place, once on-site physical testing will be possible.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	FORD	Pass	The Assisted Border crossing application has been successfully tested, as the message to perform an emergency stop was received and understood by the FORD MABX (remote integration test)
V5	The vehicle applications are correctly installed	FORD	Pass	
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	FORD, WINGS	Pass	The remote integration test between the WINGS Assisted Border crossing application and the FORD MABX was successful. All communication streams were tested and were found to operate nominally.
V7	Messages and data content and encoding has been agreed between partners.	FORD, IMEC, WINGS	Pass	All messages between the WINGS platform/application and the FORD truck were successfully transmitted/received and understood.
V8	The vehicle has safety measures in place to allow the driver to take control	FORD	Pass	
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	All GR-TR partners	Pass	At this stage, the integration tool place in a lab remotely, due to COVID restrictions. However permits from the GR and TR customs agencies have been secured.
OBU related issues				
V10	All OBUs are ready and available for the trials	IMEC, WINGS	Pass	GR-TR_UE_01 and GR-TR_UE_02 are both ready and operational
V10	All OBUs are ready and available for the trials	IMEC, WINGS	Pass	GR-TR_UE_01 and GR-TR_UE_02 are both ready and operational
V11	The OBUs are correctly installed in the CAV/CV	FORD, IMEC, WINGS	Pass	
V12	The applications in the OBU behave as expected and are validated	WINGS	Pass	Tested with dummy input and over the COSMOTE Athens 5G testbed

ID	Issue	Partner(s)	Result	Explanation
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	Not part of the OBU specifications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	WINGS, Cosmote	Pass	Tested during the June 2021 site visit at Alexandroupoli
V15	The OBUs connect and have access to the 5G network	WINGS, Cosmote	Pass	Verified for GR-TR_UE_02 over the Cosmote 5G-Testbed in Athens (identical to the one in the borders)
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	WINGS	Pass	DENM and CAM messages have been used for communication between the OBU and the platform. Successful transmission/reception on both ends has ben verified.
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured	WINGS	Pass	All roadside sensors are available and their functionality has been verified over the WINGS server GR-TR_serv_02 (Described in D3.4)
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity	WINGS, Cosmote, Turkcell	Pass	Tested during the June 2021 site visit at Alexandroupoli
I3	The infrastructure sensors connect and have access to the 5G network	WINGS	Pass	Verified for GR-TR_UE_02 over the Cosmote 5G-Testbed in Athens (identical to the one in the borders)
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding	WINGS	Pass	
I5	Synchronisation measures are used for the infrastructure	All GR-TR partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data	WINGS, Cosmote, Turkcell	Pass	Tested during the June 2021 site visit at Alexandroupoli
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	WINGS	Pass	Access to WINGS Cloud has been verified over the Athens 5Gtestbed. Google maps integration and License plate recognition SW integration have been successfully verified.
S2	External servers are connected to the network and accessible by all partners needing access	WINGS	Pass	WINGS cloud (server) is up and running and accessible with the proper credentials.

ID	Issue	Partner(s)	Result	Explanation
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	WINGS	Pass	Successfully verified
S4	Messages with the servers can be exchanged according to the relevant specifications	WINGS	Pass	DENM, CAM and proprietary messages have been successfully exchanged among both instances of the platform and the OBU and RSI.
S5	Synchronisation measures are used for the server	All GR-TR partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners
Other end-user devices (e.g. VRUs, smartphones)				
E1	Other end user devices, which are needed for the user story, are available	WINGS	Pass	Yes. Smartphone, and Road side sensors are available and their functionality and connection to the WINGS platform has been verified.
E2	End user devices are connected to the network	WINGS	Pass	Smartphones, OBU and RSI were connected to the Athens 5G-testbed
E3	The end-user devices have live connection to MEC over 4G/5G connectivity	WINGS, Cosmote, Turkcell	Pass	
E4	The application algorithms on the end-user device are installed correctly and work as expected	WINGS	Pass	Yes. Successful verification of functionality on all end-devices
E5	The end-user devices are capable to transmit the relevant (C-ITS) messages according to the relevant standard and encoding	WINGS	Pass	Yes, proper exchange of DENM and CAM messages between the OBU and the platform has been verified. The rest of the devices use proprietary messaging.
E6	Synchronisation measures are used for the server	All GR-TR partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	Cosmote, Turkcell, WINGS	Pass	WIGS is providing the mini-PC to act as an edge server in this US (GR-TR_edge_02) which is installed in the Alexandroupoli facilities of Cosmote. The connection and integration with the mini-PC has been successfully tested.
N3	MEC applications can handle the relevant C-ITS messages	WINGS	Pass	The full US functionality has been verified over the mini-PC that will act as an Edge server for this US (GR-TR_edge_02)
N4	The complete test area is covered by the 5G-networks	Cosmote, Turkcell	Pass	

ID	Issue	Partner(s)	Result	Explanation
N5	MEC access is provided for the whole test area	Cosmote, Turkcell	Pass	Accessing the WINGS edge server from the GR side of the GR-TR border was feasible throughout the tests.
N6	All MEC applications and data logging are synchronised	WINGS	Pass	The application residing at the GR-TR_edge_02, and the OBU, UEs and RSI used for this US are all using the same NTP servers as the synch source. Each of these elements produces its own log file using the NTP acquired timing. Logs have been cross-checked and verified.
N7	Data is exchanged between MECs through agreed protocols	WINGS	Partly	The WINGS application has special double-instance instantiation in order to exchange data between two instances of the applications residing at neighbouring edges. The correct functionality of this double instance data exchange has been tested and verified (successful; data exchange and status transfer of users among the instances) at WINGS premises in Athens. As the edges have not been installed at the borders due to COVID travelling restrictions, this has not been tested yet at the borders, but no issues are expected as this simply means a change in the used IPs (the functionality will be the same).
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	Cosmote, Turkcell	Pass	
N10	MEC1 can connect with MEC2 and vice-versa	Cosmote, Turkcell	Partly	Edge nodes (located at Alexandroupoli (MEC2, GR) & Istanbul (MEC1, TR)) connect to the edge DCs (at Alexandroupoli (GR) & Istanbul (TR), respectively), where the overlay vEPC functionalities are deployed, while the 5G UE – application servers' connectivity is provided over the PGW SGi interface. Thus, in order to validate connectivity between MECs, the validation of cross-core network integration is required, which is ongoing, as described above.
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	WINGS	Not relevant	This US is only instantiated via WINGS developed technology/components. 5G security protocols are used for securing communication.
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	WINGS	Pass	Yes. Encryption/Decryption (IS-128 bit Encryption) has been applied on all message exchange between the OBU, the RSU and the platform.
Logging related issues				

ID	Issue	Partner(s)	Result	Explanation
L1	Logging is in place for all components	WINGS	Pass	Yes. Three log files are generated according to the Common Data format, from the OBU, the RSU and the platform.
L2	Procedures for starting logging are in place	WINGS	Pass	Logging starts automatically with system power ON.
L3	Logging formats comply with the agreed format	WINGS	Pass	The common Data Format is used for logging. A test file has been created and uploaded to the CTS server. No errors occurred.
L4	Logged data can be uploaded to the CTS	WINGS	Pass	Yes, test file was successfully uploaded to the CTS
L5	All data required is logged	WINGS	Pass	Verified through manual checking of the output file.
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	All GR-TR partners	Partly	

Table 65: Checklist for the Assisted Border Crossing user story (Basic version)

ID	Issue	Partner(s)	Result	Explanation
N7	Data is exchanged between MECs through agreed protocols		Not relevant	The WINGS application has special double-instance instantiation in order to exchange data between two instances of the applications residing at neighbouring edges. The correct functionality of this double instance data exchange has been tested and verified (successful; data exchange and status transfer of users among the instances) at WINGS premises in Athens. As the edges have not been installed at the borders due to COVID travelling restrictions, this has not been tested yet at the borders, but no issues are expected as this simply means a change in the used IPs (the functionality will be the same).
N10	MEC1 can connect with MEC2 and vice-versa		Not relevant	Edge nodes (located at Alexandroupoli (MEC2, GR) & Istanbul (MEC1, TR)) connect to the edge DCs (at Alexandroupoli (GR) & Istanbul (TR), respectively), where the overlay vEPC functionalities are deployed, while the 5G UE – application servers' connectivity is provided over the PGW SGi interface. Thus, in order to validate connectivity between MECs, the validation of cross-core network integration is required, which is ongoing, as described above.
N11	The UEs can roam between MNO1 and MNO2		Not relevant	
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	

6.3.4 US#3.2.b: Truck Routing in Customs Area (GR-TR)

Table 66: Checklist for the Truck Routing in Customs Area user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	FORD	Pass	The vehicle is ready to integrate with the physical components and applications.
V2	The physical components are integrated and operate correctly	FORD, IMEC	Pass	Physical components integration with the vehicle is completed.
V3	The physical components, integrated in the vehicle, send the correct information	FORD, IMEC	Pass	Physical components integration with the vehicle is completed.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	FORD, TUBITAK	Pass	Testing of Autonomous Truck Routing Vehicle Application has been done at İnönü test track.
V5	The vehicle applications are correctly installed	FORD	Pass	The application installed on the vehicle but it is ready.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	FORD	Pass	Final version has been completed.
V7	Messages and data content and encoding have been agreed between partners.	FORD, IMEC	Pass	Agreed and verified with bench tests.
V8	The vehicle has safety measures in place to allow the driver to take control	FORD	Pass	The driver can take over control from the automated vehicle in critical situations with braking or steering the wheel.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	All GR-TR partners	Pass	All the necessary permissions have been given for the tests.
OBU related issues				
V10	All OBUs are ready and available for the trials	IMEC	Pass	IMEC provides the OBUs and currently are at Ford for the integration with their vehicles
V11	The OBUs are correctly installed in the CAV/CV	FORD, IMEC	Pass	Integration with vehicle is completed.
V12	The applications in the OBU behave as expected and are validated	IMEC	Pass	IMEC has tested the OBU before sending it to the Turkey.

ID	Issue	Partner(s)	Result	Explanation
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	Not part of the OBU specifications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity		Not relevant	No MEC implementation in this US.
V15	The OBUs connect and have access to the 5G network	IMEC, Turkcell	Pass	Turkcell has tested the OBUs in İstanbul.
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	IMEC	Pass	IMEC connected to TUBITAK Cloud successfully.
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	FORD	Pass	Required components implementation in completed.
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	Another component is used for positioning.
V19	Synchronisation measures are used for the OBU	All GR-TR partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners.
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured	IMEC	Pass	IMEC has completed the integration of sensors and shipped to Turkey.
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity		Not relevant	No MEC implementation in this US.
I3	The infrastructure sensors connect and have access to the 5G network	IMEC, Turkcell	Pass	5G network connection is done
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding	IMEC	Pass	IMEC has integrated and tested the sensors on RSUs.
I5	Synchronisation measures are used for the infrastructure	All GR-TR partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners.
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data		Not relevant	No edge implementation in this US.

ID	Issue	Partner(s)	Result	Explanation
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	TUBITAK	Pass	Server and application have been tested on track.
S2	External servers are connected to the network and accessible by all partners needing access	TUBITAK	Pass	Server is ready and up.
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	TUBITAK	Pass	Application is installed and tested on track.
S4	Messages with the servers can be exchanged according to the relevant specifications	TUBITAK	Pass	Integration tests have been done.
S5	Synchronisation measures are used for the server	All GR-TR partners	Pass	Specific UTP Servers have been identified and used for all GR-TR partners.
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	FORD, IMEC, TUBITAK, Turkcell	Pass	
N4	The complete test area is covered by the 5G-networks	Turkcell	Pass	Turkcell got the measurements
Privacy and security issues				
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	FORD, TUBITAK, IMEC	Pass	
Logging related issues				
L1	Logging is in place for all components	TUBITAK	Partly	Logging available but not fully covered yet
L2	Procedures for starting logging are in place	TUBITAK	Partly	It is implemented but requires more tests
L3	Logging formats comply with the agreed format	TUBITAK	Not tested	
L4	Logged data can be uploaded to the CTS	TUBITAK	Not tested	
L5	All data required is logged	TUBITAK	Partly	Logging all required data is in progress

ID	Issue	Partner(s)	Result	Explanation
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	All GR-TR partners	Not tested	

6.3.5 US#3.3: EDM-Enabled Extended Sensors with Surround View Generation (DE)

Table 67: Checklist for the EDM-Enabled Extended Sensors with Surround View Generation user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	VICOM & VALEO & TUB	Pass	Vehicles will be booked by the system for assets reservation from each entity Pictures of cars in the trial site performing session tests will be taken from team's smartphones
V2	The physical components are integrated and operate correctly	VICOM & VALEO & TUB	Pass	The vehicles include local applications to see sensor status For the communications a Speed test will be done Previously to run tests a connectivity run will be done to check connectivity (internet connection) along the path every ~200meters
V3	The physical components, integrated in the vehicle, send the correct information	VALEO	Pass	A local monitor for GNSS and Camera sensors will be performed Licenses of RTMaps applications will be checked as they need dongles or online access
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	VICOM & VALEO & TUB	Pass	With the vehicles stopped with a hardcoded native application the extended sensors without surround view will be tested Tests include 2 individual tests using Vehicle Discovery Service and one WebRTC Gateway deployed in the MEC from SA Network and using the ones deployed in the MEC for NSA Network
V5	The vehicle applications are correctly installed	VICOM & VALEO & TUB	Pass	Ping to IP addresses of MEC servers deployed in NSA and SA infrastructures is performed
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	VALEO	Pass	A local monitor for GNSS and Camera sensors will be performed For the communications a Speed test will be done Previously to run tests a connectivity run will be done to check connectivity (internet connection) along the path every ~200meters

ID	Issue	Partner(s)	Result	Explanation
V7	Messages and data content and encoding have been agreed between partners.	VICOM	Pass	ASN.1 and CPM messages are exchanged through MQTT for the Vehicle Discovery Service Standard WebRTC video sessions are performed
V8	The vehicle has safety measures in place to allow the driver to take control	VALEO	Pass	The driver have all the time the control on steering wheel, accelerator, brake and gear The extended sensors provide a wider view for situations where Line of Sight is blocked
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	TUB	Not relevant	The test will be done in an open and public road of Berlin and no permission is required as the system is operated and monitored by the co-pilot
OBU related issues				
V10	All OBUs are ready and available for the trials	VICOM & VALEO & TUB	Pass	The OBUs are directly integrated in the vehicle, so if the vehicle is available, the OBU is there
V11	The OBUs are correctly installed in the CAV/CV	VICOM & VALEO & TUB	Pass	The OBU is in the rear part of the vehicles and is powered and interfaced with regular industrial equipment
V12	The applications in the OBU behave as expected and are validated	VICOM & VALEO	Pass	Different scripts to check that the systems and components are properly running are identified, from OS management tools to RTMaps specialized pipelines to specifically test a part of the pipeline
V13	The OBUs can manage and run 3rd party CCAM applications	VICOM & VALEO	Pass	The OBU is based on Linux / Windows and can host any kind of native application developed, not only CCAM but any regular application
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	TUB & GTARC	Pass	Ping to IP addresses of MEC servers deployed in NSA and SA infrastructures is performed
V15	The OBUs connect and have access to the 5G network	TUB & GTARC	Pass	Speed test from Web Browser will be done Previously to run tests a connectivity run will be done to check connectivity (internet connection) along the path every ~200meters
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding		Pass	MQTT
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	VICOM	Pass	Atomic test for MQTT and WebRTC connectivity are performed independent of CCAM application generating logs in local files

ID	Issue	Partner(s)	Result	Explanation
V19	Synchronisation measures are used for the OBU	VICOM & VALEO & TUB & GTARC	Pass	All the systems employ a common NTP server available in internet that will be deployed in the MEC infrastructure
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	VICOM	Pass	Central MEC Registry deployed in a cloud infrastructure is reachable through Internet (and so from both MEC infrastructures)
S2	External servers are connected to the network and accessible by all partners needing access	VICOM	Pass	Central MEC Registry deployed in a cloud infrastructure is reachable through Internet (and so from both MEC infrastructures)
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	VICOM	Pass	Unit tests for new MEC instance and Update subscription will be performed
S4	Messages with the servers can be exchanged according to the relevant specifications	VICOM	Pass	Unit tests for new MEC instance and Update subscription will be performed
S5	Synchronisation measures are used for the server		Pass	Synchronisation here is out of the scope as it has no impact on potential inconsistencies
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	VICOM & VALEO & TUB & GTARC	Pass	Local tests through Internet and Foreign Mobile Infrastructures
N2	All partners have access to the needed interfaces and infrastructure	VICOM & VALEO & TUB & GTARC	Pass	Local tests through Internet and Foreign Mobile Infrastructures
N4	The complete test area is covered by the 5G-networks			Out of the scope
N5	MEC access is provided for the whole test area	VALEO & TUB & GTARC	Pass	For the communications a Speed test will be done Previously to run tests a connectivity run will be done to check connectivity (internet connection) along the path every ~200meters

ID	Issue	Partner(s)	Result	Explanation
N6	All MEC applications and data logging are synchronised	VICOM & VALEO & TUB & GTARC	Pass	Previously to run tests a connectivity run will be done to check MEC access along the path every ~1000meters with Atomic test for MQTT and WebRTC connectivity performed independent from CCAM application generating logs in local files
N7	Data is exchanged between MECs through agreed protocols	VICOM	Pass	The local logs with NTP timestamps will be offline checked ignoring the shift introduced by message delivery from distant systems
N8	The algorithms for geolocation and filtering of messages work as expected		Pass	As we are using open source libraries for MQTT, ASN.1 and WebRTC, this is out of scope
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	TUB & GTARC	Not relevant	Different Networks SA & NSA will ve overlapped and depending on Geo-position where a virtual border will trigger the roaming from a network and MEC utilization perspective, managing the MEC interconnection and session roaming from one infrastructure to another one trying to minimise the impact on CCAM application
N10	MEC1 can connect with MEC2 and vice-versa	VICOM & TUB & GTARC	Pass	The connection to both MEC infrastructures from local and foreign wired and mobile networks will be checked in advance
N11	The UEs can roam between MNO1 and MNO2		Pass	Emulated Roaming using Multi-modem/multi-SIM approach
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	VICOM & TUB	Pass	Managed by Open Source libraries based on TLS/SSL stacks
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.	VICOM & TUB	Pass	Managed by Open Source libraries based on TLS/SSL stacks
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)	VICOM & TUB	Pass	Managed by Open Source libraries based on TLS/SSL stacks
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	VICOM & TUB	Pass	Data is not recorded just used in live from surrounding vehicles that would be able to have access to that data with local sensors if the blocking line of sight situation was not present
Logging related issues				

ID	Issue	Partner(s)	Result	Explanation
L1	Logging is in place for all components	VICOM & TUB & GTARC	Pass	All the vehicle side and MEC side systems produce logs in a local file that is also read byy a daemon that pushes data to a Prometheus server
L2	Procedures for starting logging are in place	VICOM	Pass	Logs are intrinsic and configurable, in terms of sample rate, systems of the CCAM applications and MEC systems
L3	Logging formats comply with the agreed format	TUB & GTARC	Pass	Logs have been checked with WP5 requirements
L5	All data required is logged		Pass	CTS data upload workshop done
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	TUB & GTARC	Pass	Logs have been checked with WP5 requirements

6.3.6 US#3.4: Extended Sensors with Redundant Edge Processing (FI)

Table 68: Checklist for the Extended Sensors with Redundant Edge Processing user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	AALTO, SENSIBLE4	Pass	S4 CAV and AALTO CV fully owned, maintained and operated by each respective organisation.
V2	The physical components are integrated and operate correctly	AALTO, SENSIBLE4	Pass	All components operating within parameters. Verified in pre-trials on February 2021
V3	The physical components, integrated in the vehicle, send the correct information	SENSIBLE4	Pass	Connections verified in pre-demonstration on 11.-12. February 2021. LIDAR data was recorded for new experiments but not used in later trials
V7	Messages and data content and encoding have been agreed between partners.	AALTO	Pass	Connections (between video application's client and server) verified in pre-demonstration on 11.-12. February 2021
V8	The vehicle has safety measures in place to allow the driver to take control	SENSIBLE4	Pass	Vehicle has a safety driver on board during testing, who can take control of the vehicle at all times.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	SENSIBLE4	Pass	All permits necessary for testing on FI_route_01 and FI_route_02 have been obtained.
OBU related issues				
V10	All OBUs are ready and available for the trials	AALTO	Pass	Multi-PLMN OBU from Goodmill tested in both NSA and SA networks

ID	Issue	Partner(s)	Result	Explanation
V11	The OBUs are correctly installed in the CAV/CV	SENSIBLE4	Pass	OBU placed inside the vehicle connected to a power source and to the computer, with an ethernet cable. The OBU's four antennas were installed in the car's roof.
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	AALTO	Pass	Live connection between OBU and MEC tested over both experimental and commercial 5G networks
V15	The OBUs connect and have access to the 5G network	AALTO	Pass	OBU connectivity validated with three different 5G NSA mode networks (FI_MNO_01, FI_MNO_05, FI_MNO_06)
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	OBU not used for vehicle positioning, only for connectivity
V19	Synchronisation measures are used for the OBU	AALTO	Pass	Synchronisation achieved enabling 5G network connectivity
Infrastructure related issues				
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data		Pass	Tested during the pre-trials in mid-February 2021
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	AALTO	Pass	AALTO provides the server platform for the DNS and edge controllers
S2	External servers are connected to the network and accessible by all partners needing access	AALTO	Pass	Tested during the pre-trials in mid-February 2021
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	AALTO	Pass	Tested during the pre-trials in mid-February 2021
S4	Messages with the servers can be exchanged according to the relevant specifications	AALTO	Pass	Command messages from servers to vehicle (client) sent and received as specified.
S5	Synchronisation measures are used for the server	AALTO	Pass	The clocks of servers are synchronised via NTP
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications		Not relevant	All applications are developed by AALTO
N2	All partners have access to the needed interfaces and infrastructure	AALTO	Pass	All applications are developed by AALTO, and Cloud and MECs are deployed in AALTO's testbed

ID	Issue	Partner(s)	Result	Explanation
N4	The complete test area is covered by the 5G-networks	AALTO	Pass	Pre-trials testing done using FI_MNO_05 and FI_MNO_06 while covered who test route. The deployment of the second 5G site is still pending for FI_MNO_2
N5	MEC access is provided for the whole test area	AALTO	Pass	MEC access was provided for whole test area when using commercial 5G networks (limited coverage for research 5G networks)
N6	All MEC applications and data logging are synchronised	AALTO	Pass	Tested during the pre-trials in mid February 2021
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	AALTO	Pass	Network handover is managed by multi-SIM OBU and has been tested in both NSA and SA mode
N10	MEC1 can connect with MEC2 and vice-versa		Pass	MEC1 and MEC2 have connection to each other because they have public IP addresses. It is verified on both Aalto 5G research networks and commercial 5G networks. However, in this user story, there is no communication between the two MECs.
N11	The UEs can roam between MNO1 and MNO2		Partly	SA-SA roaming implemented and tested in only indoor SA networks. Testing for outdoor SA networks (MNO-3 and MNO-4) ongoing
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	AALTO	Pass	All of the communications are protected by TLS. Non-TLS messages are rejected by the servers and the clients
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	AALTO, SENSIBLE4	Pass	Video and LiDAR streamed and recorded followed GDPR guidelines
Logging related issues				
L1	Logging is in place for all components	AALTO	Pass	Each component stores its logs in its local storage. The logs are collected together after the test.
L2	Procedures for starting logging are in place	AALTO	Pass	The start script of each program also starts corresponding logging program.
L3	Logging formats comply with the agreed format	AALTO	Partly	The log analyser can successfully parse all of the logs.
L4	Logged data can be uploaded to the CTS	AALTO	Partly	We manually collect the log after testing.
L5	All data required is logged	AALTO	Partly	The log analyser checks if all logs are uploaded.

ID	Issue	Partner(s)	Result	Explanation
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	AALTO	Pass	The programming synchronising timestamps among all machines runs every 10s during the trial

6.3.7 US#3.5: Extended Sensors with CPM Messages (NL)

Table 69: Checklist for the Extended Sensors with CPM Messages user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials		Not relevant	Considering ExSe doesn't deploy CAVs but rather uses OBUs with an HMI and a manual driver, this is not relevant
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.		Pass	Vehicle = OBU
V7	Messages and data content and encoding have been agreed between partners.		Pass	Vehicle = OBU
V8	The vehicle has safety measures in place to allow the driver to take control		Not relevant	Only manual driving
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received		Not relevant	No permits are needed because only manual driving is performed on the A270
OBU related issues				
V10	All OBUs are ready and available for the trials		Pass	TNO provides the OBU
V11	The OBUs are correctly installed in the CAV/CV		Pass	The OBU and HMI setup is a standalone system and can be easily swapped in/out of any vehicle
V12	The applications in the OBU behave as expected and are validated		Pass	The lane merging/changing applciation still needs some improvements related to generating a more stable speed advice
V14	The OBUs have a live connection to MEC over 4G/5G connectivity		Pass	
V15	The OBUs connect and have access to the 5G network		Pass	

ID	Issue	Partner(s)	Result	Explanation
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding		Pass	
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)		Not relevant	Geofiltering is done on the MEC and only relevant messages are passed up to the application layer
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	Currently the OBU does not support improved positioning (GNSS is used). Improved positioning is not necessary for this use case
V19	Synchronisation measures are used for the OBU		Pass	PPS (GPS) signal is used to sync clocks. Possible clock offset can be analysed afterwards by processing clock offset statistics generated by Chrony
Infrastructure related issues				
I1	The availability of the infrastructure sensors is assured		Pass	Siemens provides roadside cameras
I2	The infrastructure sensors have live connection to MEC over 4G/5G connectivity		Not relevant	Infrastructure is connected over wire to the rabbitmq.timc.tass.international MEC
I4	The infrastructure sensors are capable to transmit and receive the relevant messages according to the relevant standard and encoding		Pass	Proprietary VBM messages
I5	Synchronisation measures are used for the infrastructure		Pass	NTP sync to stratum 1 server. Possible clock offset can be analysed afterwards by processing clock offset statistics generated by Chrony
I6	Applications at the infrastructure (edge) are working correctly and have real-time access to all required data		Pass	
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available		Pass	TNO provides a MEC application for processing output of the Siemens camera system
S2	External servers are connected to the network and accessible by all partners needing access		Pass	Infrastructure is connected over wire to the rabbitmq.timc.tass.international MEC

ID	Issue	Partner(s)	Result	Explanation
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated		Pass	
S4	Messages with the servers can be exchanged according to the relevant specifications		Pass	CPM (ETSI TR 103 562 v.0.0.15 (2019-01)) CAM (ETSI EN 302 637-2 v1.4.1 (2019-04))
S5	Synchronisation measures are used for the server		Pass	NTP sync to stratum 1 server. Possible clock offset can be analysed afterwards by processing clock offset statistics generated by Chrony
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure		Pass	
N3	MEC applications can handle the relevant C-ITS messages		Pass	CPM (ETSI TR 103 562 v.0.0.15 (2019-01)) CAM (ETSI EN 302 637-2 v1.4.1 (2019-04))
N4	The complete test area is covered by the 5G-networks		Fail	Reception at Nuenen on/off ramp is not good enough to do ExSe runs with TNO network. Lane changing manoeuvres can be performed near Neervoortse Dreef where TNO network has sufficient reception. As fallback only the KPN network will be used at Nuenen
N5	MEC access is provided for the whole test area		Pass	
N6	All MEC applications and data logging are synchronised		Pass	NTP sync to stratum 1 server. Possible clock offset can be analysed afterwards by processing clock offset statistics generated by Chrony
N7	Data is exchanged between MECs through agreed protocols		Pass	MQTT
N8	The algorithms for geolocation and filtering of messages work as expected		Pass	
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Not tested	
N10	MEC1 can connect with MEC2 and vice-versa		Pass	
N11	The UEs can roam between MNO1 and MNO2		Not tested	

ID	Issue	Partner(s)	Result	Explanation
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS ...		Pass	TLS
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Pass	
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)		Pass	
Logging related issues				
L1	Logging is in place for all components		Pass	
L2	Procedures for starting logging are in place		Pass	
L3	Logging formats comply with the agreed format		Pass	
L4	Logged data can be uploaded to the CTS		Pass	
L5	All data required is logged		Pass	
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	

6.4 UCC#4: Remote Driving

6.4.1 US#4.1: Automated Shuttle Remote Driving Across Borders (ES-PT)

Table 70: End-user devices in the Public transport user story in the ES-PT CBC

UE ID	Type of UE	UE host ID	UE host description
ES-PT_UE_04	OBU	ES-PT_veh_04	CTAG autonomous shuttle

Table 71: MECs in the Public transport user story in the ES-PT CBC

MEC/Server ID	Country	MNO ID	MEC Server Name
ES-PT_MEC_01	ES	ES-PT_MNO_02	MEC Calvario CT
ES-PT_MEC_02	PT	ES-PT_MNO_03	MEC Riba d'Ave
ES-PT_serv_03	ES	ES-PT_MNO_02	Remote Control Centre (cockpit)

Table 72: Applications in the Public transport user story in the ES-PT CBC

Application ID	Description	Installed in
ES-PT_veh_app_06	app for managing the transmission of CMD and ACK messages	ES-PT_veh_04
ES-PT_serv_app_02	app for remote driving the shuttle	ES-PT_serv_03

Table 73: Checklist for the Automated Shuttle Remote Driving Across Borders user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	CTAG Nokia ES	Pass	ES-PT_veh_04 has 5G connectivity and the required CCAM functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG	Pass	ES-PT_veh_app_06 is installed in ES-PT_veh_04 and are ready for the tests
V3	The physical components, integrated in the vehicle, send the correct information		Not relevant	ES-PT_veh_04 is not using onboard sensors
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG	Pass	ES-PT_veh_04 is accessing all the required information via CAN and is able to perform the remote driving
V5	The vehicle applications are correctly installed	CTAG	Pass	The same as V4
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	CTAG Nokia ES	Pass	ES-PT_veh_app_06 receives the information to perform the remote driving
V7	Messages and data content and encoding has been agreed between partners.	CTAG Nokia ES	Pass	ES-PT_veh_04 is receiving CMD commands to perform the remote driving and sending back ACK messages

ID	Issue	Partner(s)	Result	Explanation
V8	The vehicle has safety measures in place to allow the driver to take control	CTAG	Pass	Changing from autonomous driving to manual driving Pushing the emergency button
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	CTAG CCG	Pass	The national traffic authorities in ES and PT have provided time slots to perform the final tests in open road but the verification tests are performed in a controlled environment for safety reasons
OBU related issues				
V10	All OBUs are ready and available for the trials	CTAG	Pass	ES-PT_UE_04 is provided by CTAG
V11	The OBUs are correctly installed in the CAV/CV	CTAG	Pass	ES-PT_UE_04 is located under the seats, connected to the power supply of the shuttle using "banana plugs". The modem is connected to an antenna on the roof of the vehicle.
V12	The applications in the OBU behave as expected and are validated	CTAG	Pass	ES-PT_UE_04 is checked by means of a SSH connection to verify that all the processes are running
V13	The OBUs can manage and run 3rd party CCAM applications		Not relevant	No 3rd party CCAM applications
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	CTAG Nokia ES	Pass	Checked by a ping from ES-PT_UE_04 to ES-PT_MEC_01 (averaged ping latency is 24ms)
V15	The OBUs connect and have access to the 5G network	CTAG Nokia ES Nokia PT	Pass	ES-PT_UE_04: checked by accessing radio parameters of the modem and identifying ES-PT_MNO_01 and ES-PT_MNO_03 and the 5G bands
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	CTAG Nokia ES Nokia PT	Pass	ES-PT_UE_04 are publishing and receiving messages to the ES-PT_ MEC_01 (verified by means of the application logs)
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	CTAG Nokia ES	Pass	Geolocation data is received and passed to the upper layers and protocols from the RSU.
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG	Pass	ES-PT_UE_04 uses differential GPS positioning

ID	Issue	Partner(s)	Result	Explanation
V19	Synchronisation measures are used for the OBU	CTAG	Pass	ES-PT_UE_04 has implemented synchronization using NTP and PPS correction
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	Nokia ES	Pass	ES-PT_serv_01 is provided by Nokia ES
S2	External servers are connected to the network and accessible by all partners needing access	CTAG Nokia ES	Pass	ES-PT_serv_01 is sending CMD messages to ES-PT_veh_04 and receiving back the ACK command
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	CTAG Nokia ES	Pass	The same as S2
S4	Messages with the servers can be exchanged according to the relevant specifications	CTAG Nokia ES	Pass	The same as S2
S5	Synchronisation measures are used for the server	Nokia ES	Pass	Single NTP server with low stratum coming from NOS is being used as reference time for all MEC appliances. UE clients make use of GPS synchro.
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	Nokia ES	Pass	ES-PT_MEC_app_02 in ES-PT_MEC_01 is managing the CMD and ACK messages between ES-PT_UE_04 and ES-PT_MEC_01
N2	All partners have access to the needed interfaces and infrastructure	Nokia ES	Pass	The same as N1
N3	MEC applications can handle the relevant C-ITS messages	Nokia ES	Pass	The same as N1
N4	The complete test area is covered by the 5G-networks		Pass	Tested with a coverage map
N5	MEC access is provided for the whole test area	Nokia ES	Pass	Both MEC instances available providing access to NOS radio zone and Telefonica radio zone
N6	All MEC applications and data logging are synchronised	Nokia ES	Pass	Logging available and verified in ES-PT_MEC_01 and ES-PT_MEC_02

ID	Issue	Partner(s)	Result	Explanation
N7	Data is exchanged between MECs through agreed protocols	Nokia ES	Pass	Both MECs are able to forward tunnelling connections using ports 2020 and 2021 in UDP used for remote driving. VPN Clients are seamlessly connected to SP MEC regardless they are in the Spanish radio or Portuguese radio coverage area
N8	The algorithms for geolocation and filtering of messages work as expected		Pass	Post-process scripts developed aggregate date for GIS geolocation applications.
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests satisfactory by using the OBUs with US data
N10	MEC1 can connect with MEC2 and vice-versa	Nokia ES Nokia PT NOS Telefónica	Pass	Connectivity tests done via direct IP connections across VMs Also tested with internal VPN Server
N11	The UEs can roam between MNO1 and MNO2	Nokia ES Nokia PT NOS Telefónica	Pass	First tests with home routed already executed satisfactorily in both directions (ES-PT and PT-ES)
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS …	Nokia ES Nokia PT	Pass	ES-PT_MEC_01 and ES-PT_MEC_02 are VPN
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.	Nokia ES Nokia PT	Pass	Access to network is granted through provisioning SIM cards
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Not relevant	There is no storage of such data.
Logging related issues				

ID	Issue	Partner(s)	Result	Explanation
L1	Logging is in place for all components	CTAG Nokia ES	Pass	TFT4.3.1 - 4k streaming TFT4-3-2 - Cockpit Control TFT.3.3 - Shuttle Driving
L2	Procedures for starting logging are in place		Pass	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format		Pass	Common data format followed in all the modules for the use case. Extra logging software developed for additional purposes (video)
L4	Logged data can be uploaded to the CTS		Pass	The local server to be hosted at CTAG is not yet ready
L5	All data required is logged		Pass	Al logs are in place in the COCKPIT, MEC, HMCU and Jetson boards.
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	OBU and MEC offer synchro in the range of 1ms so that logs are also synchronized

6.4.2 US#4.2: Remote Driving in a Redundant Network Environment (FI)

Table 74: Checklist for the Remote Driving in a Redundant Network Environment user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	SENSIBLE4	Pass	Sensible 4 fully owned, maintained and operated vehicle.
V2	The physical components are integrated and operate correctly	SENSIBLE4	Pass	All components operating within parameters. Verified in pre-demonstration on 11.-12. February 2021
V3	The physical components, integrated in the vehicle, send the correct information	SENSIBLE4	Pass	Connections verified in pre-demonstration on 11.-12. February 2021
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	SENSIBLE4	Pass	Applications verified by developer Sensible 4 in pre-demonstration on 11.-12. February 2021
V5	The vehicle applications are correctly installed	SENSIBLE4	Pass	Partial success during pre-demonstration on 11.-12. February 2021. Issue with initial localisation identified and correction implemented before trials of 29-30/04.

ID	Issue	Partner(s)	Result	Explanation
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	SENSIBLE4	Pass	All components, including LiDAR data, were operating within parameters. Verified in pre-demonstration on 11.-12. February 2021 and trials of 29-30/04
V7	Messages and data content and encoding have been agreed between partners.	SENSIBLE4	Pass	Vehicle sends message to Jetson to start the camera recording, the message type is URI type.
V8	The vehicle has safety measures in place to allow the driver to take control	SENSIBLE4	Pass	Vehicle has a safety driver on board during testing, who can take control of the vehicle at all times.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	SENSIBLE4	Pass	All permits necessary for testing on FI_route_01 and FI_route_02 have been obtained.
OBU related issues				
V10	All OBUs are ready and available for the trials	AALTO	Pass	Multi-PLMN OBU from Goodmill tested in both NSA and SA networks
V11	The OBUs are correctly installed in the CAV/CV	SENSIBLE4	Pass	OBU placed inside the vehicle connected to a power source and to the computer, with a ethernet cable. The OBU's four antennas were installed in the car's roof.
V15	The OBUs connect and have access to the 5G network	AALTO	Pass	OBU connectivity validated with three different 5G NSA mode networks (FI_MNO_01, FI_MNO_05, FI_MNO_06)
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	OBU not used for vehicle positioning, only for connectivity (COTS GPS antenna attached to OBU)
V19	Synchronisation measures are used for the OBU	AALTO	Pass	Synchronisation achieved enabling 5G network connectivity
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	AALTO	Pass	AALTO provides the server platform for the ROC/RCC and LEVIS server
S2	External servers are connected to the network and accessible by all partners needing access	AALTO	Pass	Tested during the pre-trials in mid-February 2021
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	AALTO, SENSIBLE4	Pass	LEVIS and remote driving applications tested in pre-trials in mid February 2021

ID	Issue	Partner(s)	Result	Explanation
S4	Messages with the servers can be exchanged according to the relevant specifications	SENSIBLE4	Pass	Status messages from vehicle to ROC/RCC and command messages from ROC/RCC to vehicle sent and received as specified.
S5	Synchronisation measures are used for the server	AALTO, SENSIBLE4	Pass	Synchronization achieved with NTP protocol for ROC and LEVIS servers
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	AALTO, SENSIBLE4	Pass	Interfacing between LEVIS and remoting driving components (AD system, ROC/RCC) tested
N4	The complete test area is covered by the 5G-networks	AALTO	Partly	Pre-trials testing done using FI_MNO_05 and FI_MNO_06 while covered who test route. The deployment of the second 5G site is still pending for FI_MNO_2
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	AALTO	Pass	Network handover is managed by multi-SIM OBU and has been tested in both NSA and SA mode
N11	The UEs can roam between MNO1 and MNO2	AALTO	Partly	SA-SA roaming implemented and tested in only indoor SA networks. Testing for outdoor SA networks (MNO-3 and MNO-4) ongoing
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS …	AALTO, SENSIBLE4	Pass	Encryption of traffic sent between vehicle and ROC/RCC implemented and tested
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	AALTO, SENSIBLE4	Pass	Video streamed and recorded by the LEVIS platform followed GDPR guidelines as also noted in D3.5
Logging related issues				
L1	Logging is in place for all components	AALTO, SENSIBLE4	Pass	KPI logging currently done for both the remote driving application and LEVIS app traffic flows
L2	Procedures for starting logging are in place	AALTO, SENSIBLE4	Pass	Procedures in place only for the remote driving application and LEVIS app traffic flows
L3	Logging formats comply with the agreed format	AALTO, SENSIBLE4	Pass	Currently produced measurement logs in default format of the DEKRA test tool. DEKRA has provided a script for conversion to the 5G-MOBIX common data format
L4	Logged data can be uploaded to the CTS	AALTO	Partly	Testing done during training session for upload of data to CTS with the CTS admin

ID	Issue	Partner(s)	Result	Explanation
L5	All data required is logged	AALTO, SENSIBLE4	Pass	KPI logging currently done for both the remote driving application and LEVIS traffic flows
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	AALTO, SENSIBLE4	Pass	Validity of timestamps validated for both the remote driving application and LEVIS traffic flows

6.4.3 US#4.3: Remote Driving using 5G Positioning (NL)

Table 75: Checklist for the Remote Driving using 5G Positioning user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020 -> planning described in WP4
V2	The physical components are integrated and operate correctly		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020 & 29 January 2021 on Vaarle
V3	The physical components, integrated in the vehicle, send the correct information		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020 & 29 January 2021 on Vaarle
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020 & 29 January 2021 on Vaarle
V5	The vehicle applications are correctly installed		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020 & 29 January 2021 on Vaarle
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020 - fleet management, gateway and vehicle
V7	Messages and data content and encoding have been agreed between partners.		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020
V8	The vehicle has safety measures in place to allow the driver to take control		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020, with safety drivers to be able to take over control at any time (taking into account reaction time of driver)

ID	Issue	Partner(s)	Result	Explanation
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received		Pass	For Nuenen test site, the test site needs to be blocked. NL consortium is preparing this with government and traffic regulation companies. -> for first trial tests week 13-2021 this is arranged
OBU related issues				
V10	All OBUs are ready and available for the trials		Pass	2 OBUs for remote driving functions are available. 1 OBU for 5G-positioning is in developed and tested in lab environment and planned for outside testing Mar-Apr 2022 (delayed)
V11	The OBUs are correctly installed in the CAV/CV		Partly	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020 with 2 OBUs. 1 5G-positioning OBU not yet installed (see V10)
V12	The applications in the OBU behave as expected and are validated		Partly	2 OBUs for remote driving functions and testing remote driving positioning are behaving as expected 1 OBU for 5G-(mm-wave) positioning under development (see V10) -> focus mainly on simulation now to verify
V14	The OBUs have a live connection to MEC over 4G/5G connectivity		Pass	SISSBV and TU/e-AIIM vehicle have been tested and successfully demonstrated for demo PO review 3 December 2020
V15	The OBUs connect and have access to the 5G network		Pass	Tested and confirmed on KPN network, further testing on TNO and TU/e networks still to be performed
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding		Pass	Remote driving application works, indicating the relevant messages and encoding is implemented correctly
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)		Partly	Remote driving function - passed Localisation - work in progress
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Partly	Work in progress, running in simulation -> tests to be planned Q2-2022
V19	Synchronisation measures are used for the OBU		Pass	Tested in SISSBV and AIIM-TU/e vehicles and on both remote driving stations
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available		Pass	Both remote stations are tested and working as expected (last integration with TU/e remote station tested on 29-01-2021)

ID	Issue	Partner(s)	Result	Explanation
S2	External servers are connected to the network and accessible by all partners needing access		Pass	Accessible by those who need to use them in trials
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated		Pass	
S4	Messages with the servers can be exchanged according to the relevant specifications		Pass	
S5	Synchronisation measures are used for the server		Partly	implemented on 2 vehicles and 1 remote station, to be implemented still for other remote station
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure		Pass	
N4	The complete test area is covered by the 5G-networks		Partly	- KPN network available on Vaarle, functionality tested succesfully: tested remote driving function on Vaarle. - PASS - TU/e network to be implemented and tested >Q2-3 2022 - PARTLY
N6	All MEC applications and data logging are synchronised		Pass	KPN MEC has been synchronized using NTP
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Not tested	handover between KPN - TNO network being developed
N10	MEC1 can connect with MEC2 and vice-versa		Not tested	handover between KPN - TNO network being developed
Privacy and security issues				
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.		Pass	Remote stations and vehicles use certificates to grant access to each other; tested and system works
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Pass	
Logging related issues				
L1	Logging is in place for all components		Pass	see NL_RemoteDriving_testplan_v0.1.docx

ID	Issue	Partner(s)	Result	Explanation
L2	Procedures for starting logging are in place		Pass	see NL_RemoteDriving_testplan_v0.1.docx
L3	Logging formats comply with the agreed format		Partly	complies with NL trial site procedures -> TNO to verify this
L4	Logged data can be uploaded to the CTS		Partly	NL trial site data upload is centrally organized by TNO
L5	All data required is logged		Partly	Test data from Mar/Apr 2021 and Sept. 2021 to be uploaded and shared with TNO for verification
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Partly	

Table 76: Checklist for the Remote Driving using 5G Positioning user story: Basic version (Remote driving) – differences with full version

ID	Issue	Partner(s)	Result	Explanation
V11	The OBUs are correctly installed in the CAV/CV		Pass	Yes
V12	The applications in the OBU behave as expected and are validated		Pass	Yes
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)		Pass	Yes
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Not relevant	not relevant for basic version, only for advanced version
N4	The complete test area is covered by the 5G-networks		Pass	Yes
L3	Logging formats comply with the agreed format		Pass	Yes
L4	Logged data can be uploaded to the CTS		Pass	Yes
L5	All data required is logged		Pass	Yes
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	Yes

6.4.4 US#4.4: Remote Driving with Data Ownership Focus (CN)

Table 77: Checklist for the Remote Driving with Data Ownership Focus user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	SDIA	Passs	The OBU of CN_veh_05 was ready.
V2	The physical components are integrated and operate correctly	SDIA, DATANG	Pass	Physical components integration with CN_veh_05 was ready
V3	The physical components, integrated in the vehicle, send the correct information	SDIA, DATANG	Pass	Physical components integration with CN_veh_05 was ready in April-20
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	SDIA, DATANG, DUT	pass	After readiness of CN_veh_05 and MQTT client, tests have been initiated.
V5	The vehicle applications are correctly installed	SDIA, DATANG, DUT	Pass	The applications were developed and tested by DUT
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	SDIA, DATANG, DUT	Pass	Vehicle applications were verified by DUT and SDIA
V7	Messages and data content and encoding have been agreed between partners.	SDIA, DUT	Pass	Agreed
V8	The vehicle has safety measures in place to allow the driver to take control	SDIA	Pass	The drivers can take over control from the automated vehicle in critical situations with braking or steering the wheel
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	All CN partners	Pass	All the necessary permissions have been given for the tests
OBU related issues				
V10	All OBUs are ready and available for the trials	DATANG	Pass	DATANG provides the OBUs and currently are at SDIA for the integration with their vehicles
V11	The OBUs are correctly installed in the CAV/CV	DATANG, SDIA	Pass	Integration with vehicle has been ready

ID	Issue	Partner(s)	Result	Explanation
V12	The applications in the OBU behave as expected and are validated	DATANG, SDIA	Pass	DATANG has tested the OBU before sending it to the SDIA
V15	The OBUs connect and have access to the 5G network		Pass	DATANG has tested 5G connection of the OBU in Shanghai city
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	DATANG, DUT	pass	5G OBU connectivity in this US has been tested
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	SDIA, DUT	Partly	Geolocation messaging components implementation is in progress.
V19	Synchronisation measures are used for the OBU	All CN partners	Pass	A confirmed NTP server is used for all CN partners
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	SDIA, DUT	Partly	MQTT Client on OBU is not tested.
S2	External servers are connected to the network and accessible by all partners needing access	SDIA	Pass	SDIA has tested the connection and accessibility of the servers
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	SDIA	Pass	Required components were ready
S4	Messages with the servers can be exchanged according to the relevant specifications	SDIA, DUT	Pass	Required components were ready
S5	Synchronisation measures are used for the server	All CN partners	Pass	
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	All CN partners	Pass	
N3	MEC applications can handle the relevant C-ITS messages		Not relevant	MEC is not available in this US

ID	Issue	Partner(s)	Result	Explanation
N4	The complete test area is covered by the 5G-networks	SDIA	Pass	
N5	MEC access is provided for the whole test area	SDIA	Pass	
N6	All MEC applications and data logging are synchronised	SDIA	Pass	
N7	Data is exchanged between MECs through agreed protocols	SDIA	Pass	
N8	The algorithms for geolocation and filtering of messages work as expected	SDIA	Pass	
Network handover related issues				
N11	The UEs can roam between MNO1 and MNO2	DATANG	Pass	
Privacy and security issues				
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)	All CN partners	Pass	
Logging related issues				
L1	Logging is in place for all components	DUT, SDIA	Pass	logging in on-board computer of vehicle and cloud server for controller message has been tested.
L2	Procedures for starting logging are in place	DUT, SDIA	Pass	Related messages will be logged at the onboard computer in the vehicle
L3	Logging formats comply with the agreed format	DUT, SDIA	Pass	Required components were ready
L4	Logged data can be uploaded to the CTS	DUT, SDIA	Pass	Required components were ready
L5	All data required is logged	DUT, SDIA	Pass	Required components were ready
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	All CN partners	Partly	

6.4.5 US#4.5: Remote Driving using mmWave Communication (KR)

Table 78: Checklist for the Remote Driving using mmWave Communication user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	KATECH, Renault	Pass	Test vehicle (Renault Arkana) is ready and available for the RCV trial in KR trial site.
V2	The physical components are integrated and operate correctly	KATECH	Pass	The physical components such as vehicle gateway, around view monitoring system, user interface module, network devices integrated and operated well.
V3	The physical components, integrated in the vehicle, send the correct information	KATECH	Pass	The field trial conducted on a proving ground at KATECH, demonstrating that test vehicle transmits RCV(Remote Controlled Vehicle) data such as status, sensing acquisition, GPS location and 5 video streams (around view, front, left, right and rear) to the remote server and remote server transmits control data (steering, accel, brake, etc) to the RCV through the network, was successful.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	KATECH	Pass	Network based remote driving and vehicle status monitoring application is well operated and validated.
V5	The vehicle applications are correctly installed	KATECH	Pass	Developed RCV application is well installed in the test vehicle.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	KATECH, Renault	Pass	In vehicle network is well accessed by developed vehicle gateway and required data is monitored in real time via network
V7	Messages and data content and encoding have been agreed between partners.	KATECH, Renault	Pass	Both vehicle status and ADAS related messages are well encoded between KATECH and Renault.
V8	The vehicle has safety measures in place to allow the driver to take control	KATECH	Pass	The test vehicle is tested in the KATECH's private proving ground.
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	KATECH	Pass	The test vehicle is only tested in the KATECH's private proving ground with a permission.
OBU related issues				
V10	All OBUs are ready and available for the trials	ETRI	Pass	ETRI provides the OBU for the user story of Tethering via Vehicle, and with the OBU, the field trial conducted on a highway test track was done successfully
V11	The OBUs are correctly installed in the CAV/CV	ETRI	Pass	The radio and physical layer of OBU is installed on the roof of the CAV and connected to other components inside the CAV

ID	Issue	Partner(s)	Result	Explanation
V12	The applications in the OBU behave as expected and are validated	ETRI	Pass	Through indoor and outdoor tests, we verified the functionalities of the OBU (e.g. transmitting/receiving data to/from the gNB) by checking the data rate and BLER of the communication link
V15	The OBUs connect and have access to the 5G network	ETRI	Pass	The 5G network including 5G core and gNB has been developed and testbed by ETRI
V19	Synchronisation measures are used for the OBU	ETRI	Pass	Timing and frequency synchronization can be done by receiving synchronization signal from the network
Infrastructure related issues				
I5	Synchronisation measures are used for the infrastructure	KATECH	Pass	Synchronization module for providing synchronization/accurate timing is implemented on the system
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	KATECH	Pass	External servers are connected to the 5G network developed by KATECH. External sensor is not related to the user story
S2	External servers are connected to the network and accessible by all partners needing access	KATECH	Pass	Authorization for access was shared with all partners needing access
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	KATECH	Pass	Developed external server is well installed and validated
S4	Messages with the servers can be exchanged according to the relevant specifications	KATECH	Partly	Messages with servers can be exchanged based on self-defined message exchange specification
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS …	KATECH	Pass	Exchange messages using TLS
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.	KATECH	Pass	
Logging related issues				
L1	Logging is in place for all components	KATECH	Pass	Data monitoring and logging are supported for most of components
L2	Procedures for starting logging are in place	KATECH	Pass	Different logging procedures are supported for each component
L3	Logging formats comply with the agreed format	KATECH	Pass	Logging formats comply with the agreed format between related partners

ID	Issue	Partner(s)	Result	Explanation
L4	Logged data can be uploaded to the CTS	KATECH	Pass	All logged data can be uploaded to the CTS
L5	All data required is logged	KATECH	Pass	All required logged data has been tested
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	KATECH	Pass	The timestamp of the logged data is based on GPS time.

6.5 UCC#5: Vehicle QoS Support

6.5.1 US#5.1: Public Transport with HD Media Services and Video Surveillance (ES-PT)

Table 79: End-user devices in the QoS user story in the ES-PT CBC

UE ID	Type of UE	UE host ID	UE host description
ES-PT_UE_14	Router 5G	ES-PT_veh_05	ALSA connected bus

Table 80: MECs in the QoS user story in the ES-PT CBC

MEC/Server ID	Country	MNO ID	MEC Server Name
ES-PT_serv_04	ES and PT	ES-PT_MNO_01 ES_PT_MNO_02	ALSA Control Centre
ES-PT_serv_05	Es and PT	ES-PT_MNO_01 ES-PT_MNO_02	Multimedia Server

Table 81: Applications in the QoS user story in the ES-PT CBC

Application ID	Description	Installed in
ES-PT_veh_app_07	app for sending the 4k video	ES-PT_veh_05
ES-PT_veh_app_08	app for receiving the video streaming	ES-PT_veh_05
ES-PT_serv_app_02	ALSA Control Centre	ES-PT_serv_04
ES-PT_serv_app_03	Multimedia Server	ES-PT_serv_05

Table 82: Checklist for the Public Transport with HD Media Services and Video Surveillance user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	ALSA CTAG	Pass	ES-PT_veh_05 have 5G connectivity and the required functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG	Pass	ES-PT_veh_app_07 is installed in ES-PT_veh_05 and it is ready for the tests
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG	Pass	ES-PT_veh_app_07 in ES-PT_veh_05 is receiving the multimedia content
V5	The vehicle applications are correctly installed	CTAG	Pass	The same as V4
V7	Messages and data content and encoding has been agreed between partners.	CTAG	Pass	ES-PT_veh_app_07 is using video standards
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	ALSA	Pass	This test is performed in open road during a route of the bus with real passengers
OBU related issues				
V10	All OBUs are ready and available for the trials	CTAG	Pass	ES-PT_UE_14 is a 5G router provided by CTAG
V11	The OBUs are correctly installed in the CAV/CV	CTAG	Pass	ES-PT_UE_14 is receiving the multimedia content from the multimedia server and distributing it to the tablets on the bus
V12	The applications in the OBU behave as expected and are validated	CTAG	Pass	The same as V11
V15	The OBUs connect and have access to the 5G network	CTAG	Pass	ES-PT_UE_14 connection to 5G network is checked by visual inspection of the router's display and also with a ping to ES-PT_ MEC_01
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG	Pass	ES-PT_veh_05 uses differential GPS positioning
V19	Synchronisation measures are used for the OBU	CTAG	Pass	ES-PT_UE_14 has implemented synchronization using NTP and PPS correction
External servers/ ITS Centers				

ID	Issue	Partner(s)	Result	Explanation
S1	External servers and software, which are needed for the user story, are available	ALSA	Pass	ES-PT_serv_04 is provided by ALSA
S2	External servers are connected to the network and accessible by all partners needing access	ALSA	Pass	ES_PT_serv_04 is on the Cloud
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	CTAG ALSA	Pass	The communication between ES-PT_veh_05 on the 5GMobix network and ES-PT_serv_04 on the Cloud is checked
S5	Synchronisation measures are used for the server	ALSA	Partly	ES-PT_UE_serv_04 is fine tuning the synchronization
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	CTAG	Pass	ES-PT_UE_14 is accessing to the internet through ES-PT_MEC_01
N4	The complete test area is covered by the 5G-networks	CTAG	Pass	Tested with a coverage map
N5	MEC access is provided for the whole test area	CTAG	Pass	Tested running the ES-PT_serv_app_02 and ES-PT_veh_app_07
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Partly	Starting to test
N10	MEC1 can connect with MEC2 and vice-versa		Not relevant	
N11	The UEs can roam between MNO1 and MNO2		Partly	Starting to test
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	ALSA Nokia ES Nokia PT	Pass	1) ES-PT_MEC_01 and ES-PT_MEC_02 are VPN 3) ES-PT_serv_app_04 is sFTP

ID	Issue	Partner(s)	Result	Explanation
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.	NOS Telefónica	Pass	Access to network is granted through provisioning SIM cards.
Logging related issues				
L1	Logging is in place for all components	ALSA CTAG	Pass	TFT5.2.1 - 4k streaming between the camera and the ALSA Control Center Logging in the PC connected to the camera and the ALSA Control Center
L2	Procedures for starting logging are in place		Not relevant	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format	CTAG	Partly	The tools to convert the raw data into the common data format are being developed
L4	Logged data can be uploaded to the CTS	CTAG	Not tested	
L5	All data required is logged	ALSA CTAG	Pass	ES-PT_veh_15 and ES_PT_serv_04 are logging at the network level
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	ALSA CTAG	Partly	Working on the ES-PT_UE_14 and ES-PT_serv_03 synchronization

6.5.2 US#5.2: Tethering via Vehicle using mmWave Communication (KR)

Table 83: Checklist for the Tethering via Vehicle using mmWave Communication user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials		Pass	Two test vehicles were purchased and available for the trials of two user stories in KR trial site anytime
V2	The physical components are integrated and operate correctly		Pass	The field trial conducted on a highway test track, demonstrating that multimedia services can be provided to onboard passengers' devices through the network, was successful
V3	The physical components, integrated in the vehicle, send the correct information		Pass	The field trial conducted on a highway test track, demonstrating that multimedia services can be provided to onboard passengers' devices through the network, was successful

ID	Issue	Partner(s)	Result	Explanation
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received		Pass	The vehicle has permission to drive on a highway test track in Yeoju, Korea
OBU related issues				
V10	All OBUs are ready and available for the trials		Pass	ETRI provides the OBU for the user story of Tethering via Vehicle, and with the OBU, the field trial conducted on a highway test track was done successfully
V11	The OBUs are correctly installed in the CAV/CV		Pass	The radio and physical layer of OBU is installed on the roof of the CAV and connected to other components inside the CAV
V12	The applications in the OBU behave as expected and are validated		Pass	Through indoor and outdoor tests, we verified the functionalities of the OBU (e.g. transmitting/receiving data to/from the gNB) by checking the data rate and BLER of the communication link
V15	The OBUs connect and have access to the 5G network		Pass	The 5G network including 5G core and gNB has been developed and testbed by ETRI
V19	Synchronisation measures are used for the OBU		Pass	Timing and frequency synchronization can be done by receiving synchronization signal from the network
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available		Pass	External servers are connected to the 5G network developed by ETRI. External sensor is not related to the user story.
S2	External servers are connected to the network and accessible by all partners needing access		Pass	Authorization for access was shared with all partners needing access.
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated		Pass	
S4	Messages with the servers can be exchanged according to the relevant specifications		Pass	
Other end-user devices (e.g. VRUs, smartphones)				
E1	Other end-user devices, which are needed for the user story, are available		Pass	End-user devices were purchased by ETRI so that the devices are available for testing anytime
E2	End-user devices are connected to the network		Pass	The field trial conducted on a highway test track, demonstrating that multimedia services can be provided to onboard passengers' devices through the network, was successful

ID	Issue	Partner(s)	Result	Explanation
E4	The application algorithms on the end-user device are installed correctly and work as expected		Pass	
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure		Pass	Authorization for access was shared with all partners needing access
N4	The complete test area is covered by the 5G-networks		Pass	The field trial conducted on a highway test track, demonstrating that multimedia services can be provided to onboard passengers' devices through the network, was successful
Logging related issues				
L1	Logging is in place for all components		Partly	Data monitoring and logging are supported for most of components
L2	Procedures for starting logging are in place		Pass	Different logging procedures are supported for each component
L3	Logging formats comply with the agreed format		Not tested	Different types of logging are supported for each component
L4	Logged data can be uploaded to the CTS		Pass	Part of the logged data (data rate, BLER, etc) can be delivered to the CTS in real time
L5	All data required is logged		Pass	All required logged data has been tested
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Not tested	

6.6 Contribution of the local trial sites to the CBCs

6.6.1 Contribution of TS FR to CBC ES-PT: 5G Connected Car

Table 84: Checklist for the 5G connected car user story

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	ALSA CTAG	Pass	ES-PT_veh_05 have 5G connectivity and the required functions integrated for the execution of the test cases
V2	The physical components are integrated and operate correctly	CTAG	Pass	ES-PT_veh_app_07 is installed in ES-PT_veh_05 and it is ready for the tests
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	CTAG	Pass	ES-PT_veh_app_07 in ES-PT_veh_05 is receiving the multimedia content
V5	The vehicle applications are correctly installed	CTAG	Pass	The same as V4
V7	Messages and data content and encoding has been agreed between partners.	CTAG	Pass	ES-PT_veh_app_07 is using video standards
V9	Permits: all necessary permits for performing the tests, including driving on public roads, have been received	ALSA	Pass	This test is performed in open road during a route of the bus with real passengers
OBU related issues				
V10	All OBUs are ready and available for the trials	CTAG	Pass	ES-PT_UE_14 is a 5G router provided by CTAG
V11	The OBUs are correctly installed in the CAV/CV	CTAG	Pass	ES-PT_UE_14 is receiving the multimedia content from the multimedia server and distributing it to the tablets on the bus
V12	The applications in the OBU behave as expected and are validated	CTAG	Pass	The same as V11
V15	The OBUs connect and have access to the 5G network	CTAG	Pass	ES-PT_UE_14 connection to 5G network is checked by visual inspection of the router's display and also with a ping to ES-PT_ MEC_01

ID	Issue	Partner(s)	Result	Explanation
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	CTAG	Pass	ES-PT_veh_05 uses differential GPS positioning
V19	Synchronisation measures are used for the OBU	CTAG	Pass	ES-PT_UE_14 has implemented synchronization using NTP and PPS correction
External servers/ ITS Centers				
S1	External servers and software, which are needed for the user story, are available	ALSA	Pass	ES-PT_serv_04 is provided by ALSA
S2	External servers are connected to the network and accessible by all partners needing access	ALSA	Pass	ES_PT_serv_04 is on the Cloud
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated	CTAG ALSA	Pass	The communication between ES-PT_veh_05 on the 5GMobix network and ES-PT_serv_04 on the Cloud is checked
S5	Synchronisation measures are used for the server	ALSA	Partly	ES-PT_UE_serv_04 is fine tuning the synchronization
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	CTAG	Pass	ES-PT_UE_14 is accessing to the internet through ES-PT_MEC_01
N4	The complete test area is covered by the 5G-networks	CTAG	Pass	Tested with a coverage map
N5	MEC access is provided for the whole test area	CTAG	Pass	Tested running the ES-PT_serv_app_02 and ES-PT_veh_app_07
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Partly	Starting to test
N11	The UEs can roam between MNO1 and MNO2		Partly	Starting to test

ID	Issue	Partner(s)	Result	Explanation
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS…	ALSA Nokia ES Nokia PT	Pass	1) ES-PT_MEC_01 and ES-PT_MEC_02 are VPN 3) ES-PT_serv_app_04 is sFTP
P2	All partners have agreed on the processes for exchanging certificates and have access to the agreed certificates.	NOS Telefónica	Pass	Access to network is granted through provisioning SIM cards.
Logging related issues				
L1	Logging is in place for all components	ALSA CTAG	Pass	TFT5.2.1 - 4k streaming between the camera and the ALSA Control Center Logging in the PC connected to the camera and the ALSA Control Center
L2	Procedures for starting logging are in place		Not relevant	Components are logging all the time and the partitioning is performed in postprocess using the timestamp
L3	Logging formats comply with the agreed format	CTAG	Partly	The tools to convert the raw data into the common data format are being developed
L4	Logged data can be uploaded to the CTS	CTAG	Not tested	
L5	All data required is logged	ALSA CTAG	Pass	ES-PT_veh_15 and ES_PT_serv_04 are logging at the network level
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	ALSA CTAG	Partly	Working on the ES-PT_UE_14 and ES-PT_serv_03 synchronization

6.6.2 Contribution of TS NL to CBC ES-PT: MCS Application

Table 85: Checklist for the contribution of the NL trial site to the ES-PT CBC

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	VTT CTAG	pass	The OBUs are not integrated in the vehicle and will be installed in the CTAG vehicles. Availability of the vehicles has been agreed with CTAG.
OBU related issues				
V10	All OBUs are ready and available for the trials	VTT	pass	Two OBUs have been prepared for VTT for the ES-PT trials. The OBUs consist of laptop, GNSS receiver and Huawei modem
V12	The applications in the OBU behave as expected and are validated	VTT	Pass	The applications have been tested in Finland and in the Netherlands for low speeds, and on the CTAG track for high speeds
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	VTT	Pass	The OBUs can connect to the Spanish MEC
V15	The OBUs connect and have access to the 5G network	VTT	Partly	The OBU can connect to the Spanish network with the Telefonica SIM, but not to the Portuguese network
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	VTT	pass	The software is the same as for CoCa.
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	VTT, CTAG	Pass	The VTT OBUs receive the messages from the other VTT OBU, from CTAG CAM and from MEC.
V18	The OBUs allow for improved positioning (compared to GNSS positioning)	VTT	Pass	VTT OBU can connect to the RTK service in Spain.

ID	Issue	Partner(s)	Result	Explanation
V19	Synchronisation measures are used for the OBU	VTT	pass	Use of chrony
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	VTT, Telefonica	pass	The MCS application has been installed in the MEC server
N2	All partners have access to the needed interfaces and infrastructure	VTT, Telefonica	pass	VTT can access the MEC
N3	MEC applications can handle the relevant C-ITS messages	vtt	pass	The MCS application is the same as for the NL trial site
N4	The complete test area is covered by the 5G-networks	CTAG	pass	Tested in the other ES-PT trials
N5	MEC access is provided for the whole test area	CTAG	pass	Tested in the other ES-PT trials
N6	All MEC applications and data logging are synchronised	VTT	Pass	Tested in ES-PT through analysis of logged files.
N8	The algorithms for geolocation and filtering of messages work as expected	VTT	Pass	The requested messages are sent and received
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		not tested	
N10	MEC1 can connect with MEC2 and vice-versa		Not relevant	Only connection to the Spanish MEC needed
N11	The UEs can roam between MNO1 and MNO2		Not tested	
Privacy and security issues				
P1	All involved partners can exchange messages using the agreed security protocols TLS, ETSI ITS …		Pass	Use of TLS at MQTT: the OBUs and MEC can connect using TLS
Logging related issues				
L1	Logging is in place for all components		pass	same logging as for NL trial site

ID	Issue	Partner(s)	Result	Explanation
L2	Procedures for starting logging are in place		pass	logging starting and stopping from OBU
L3	Logging formats comply with the agreed format		Partly	same format at for NL trial site
L4	Logged data can be uploaded to the CTS		Not tested	
L5	All data required is logged		pass	according to guidelines
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	Verified in the logs.

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6.6.3 Contribution of TS DE to CBC ES-PT: Extended Sensors solution including 5G connected car, Multi SIM OBU, PC5 RSUs and MEC instances,

Table 86: Checklist for the contribution of the DE trial site to the ES-PT CBC

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	VICOM	Pass	Verified in DE TS trials.
V2	The physical components are integrated and operate correctly	VICOM	Pass	Verified in DE TS trials.
V3	The physical components, integrated in the vehicle, sent the correct information	VICOM	Pass	Verified in DE TS trials.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	VICOM	Pass	Verified in DE TS trials.
V5	The vehicle applications are correctly installed	VICOM	Pass	Verified in DE TS trials.
V6	The vehicle application has access to all required data in real time (e.g. vehicle	VICOM	Pass	Verified in DE TS trials.

ID	Issue	Partner(s)	Result	Explanation
	data, sensor data) from other components.			
V7	Messages and data content and encoding has been agreed between partners.	VICOM	Pass	Verified in DE TS trials.
OBU related issues				
V10	All OBUs are ready and available for the trials	VICOM, TUB	Pass	Verified in DE TS trials.
V11	The OBUs are correctly installed in the CAV/CV	VICOM, TUB	Pass	Verified in DE TS trials.
V12	The applications in the OBU behave as expected and are validated	VICOM, TUB	Pass	Verified in DE TS trials.
V13	The OBUs can manage and run 3rd party CCAM applications	VICOM, TUB	Pass	Verified in DE TS trials.
V14	The OBUs have a live connection to MEC over 4G/5G connectivity	VICOM, TUB	Pass	Verified in DE TS trials.
V15	The OBUs connect and have access to the 5G network	VICOM, TUB	Pass	Verified in DE TS trials.
V16	The OBUs are capable to transmit and receive the relevant C-ITS messages according to the relevant standard and encoding	VICOM, TUB	Pass	Verified in DE TS trials.
V17	The vehicle receives the relevant messages (algorithms for geolocation and filtering of messages are working)	VICOM, TUB	Pass	Verified in DE TS trials.
V19	Synchronisation measures are used for the OBU	VICOM, TUB	Pass	Verified in DE TS trials. DEKRA's software tool is used to synchronise logs.
5G network related issues (incl. MEC issues)				
N1	The MEC can manage and run 3rd party CCAM applications	VICOM	Pass	Verified in remote tests.
N2	All partners have access to the needed interfaces and infrastructure	VICOM	Pass	Verified in remote tests.
N3	MEC applications can handle the relevant C-ITS messages	VICOM	Pass	Verified in remote tests.

ID	Issue	Partner(s)	Result	Explanation
N4	The complete test area is covered by the 5G-networks	VICOM	Pass	Verified by ES-PT CBC partners.
N5	MEC access is provided for the whole test area	VICOM	Pass	Verified by ES-PT CBC partners.
N6	All MEC applications and data logging are synchronised	VICOM, TUB	Pass	Verified in local and remote tests.
N7	Data is exchanged between MECs through agreed protocols	VICOM	Pass	Verified in remote tests. ETSI CPM messages are exchanged using MQTT.
N8	The algorithms for geolocation and filtering of messages work as expected	VICOM	Pass	Edge Dynamic Map (EDM) and Vehicle Discovery Service (VDS) validated in field tests and simulations.
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2	TUB, VICOM	Not tested	To be tested in March. The tests were delayed due to the network issues of the ES-PT CBC.
N10	MEC1 can connect with MEC2 and vice-versa	TUB, VICOM	Pass	Tested remotely.
N11	The UEs can roam between MNO1 and MNO2	TUB, VICOM	Not tested	At the moment of writing this deliverable there were still network issues in the ES-PT CBC that prevented to test this.
Privacy and security issues				
P3	All partners can produce messages according to the agreed certificate guidelines (e.g. ETSI ITS geonet headers)		Pass	
P4	Exchange of privacy related data, including vehicle related information and video, is in line with EU guidelines (GDPR, C-ITS security policy)		Pass	
Logging related issues				
L1	Logging is in place for all components		Pass	
L2	Procedures for starting logging are in place		Pass	
L3	Logging formats comply with the agreed format		Pass	
L4	Logged data can be uploaded to the CTS		Pass	
L5	All data required is logged		Pass	

ID	Issue	Partner(s)	Result	Explanation
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Pass	

6.6.4 Contribution of TS FI to CBC ES-PT: Multi SIM OBU Solution

This is an agnostic test case which is about a connectivity test. The FI multi-SIM OBU was part of pre-trials in Finland (February 11-12, 2021) and has been tested/verification then. This is not part of a specific user story with multiple verification steps. However, the sequence diagram of Figure 105 in Section 5.4.2 illustrates the basic connectivity verification steps (steps 1 and 2 connecting the multi-SIM OBU to the CBC networks; instead to the multi-PLMN testbed in Finland).

Table 87: Checklist for the Multi SIM OBU solution from the FI trial site to the ES-PT CBC

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	VEDECOM	Pass	A connected vehicle is ready for the contribution. Note: FI-TS will use vehicle from FR-TS in the CBC
V2	The physical components are integrated and operate correctly	VEDECOM	Pass	Equipment is integrated in the vehicle.
V3	The physical components, integrated in the vehicle, sent the correct information	VEDECOM	Pass	OK
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	VEDECOM	Pass	OK
V5	The vehicle applications are correctly installed	VEDECOM	Pass	The applications developed should run without failure in the component, where they were installed.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	VEDECOM	Pass	Test if the applications developed can receive information from other applications, if needed, and for the physical components where they should receive information
OBU related issues				
V10	All OBUs are ready and available for the trials	AALTO	Pass	Tested in Finland

ID	Issue	Partner(s)	Result	Explanation
V11	The OBUs are correctly installed in the CAV/CV	AALTO	Partly	Deployed in AALTO vehicles should be same setup for VED vehicle
V12	The applications in the OBU behave as expected and are validated	AALTO	Pass	Tested in Finland
V15	The OBUs connect and have access to the 5G network	AALTO	Pass	Tested in FI-TS 5G networks in both NSA and SA modes
V19	Synchronisation measures are used for the OBU		Pass	Tested in Finland
5G network related issues (incl. MEC issues)				
N2	All partners have access to the needed interfaces and infrastructure	CTAG	Pass	SIM cards for NOS and Telefonica networks provided to AALTO
N4	The complete test area is covered by the 5G-networks	CTAG, NOS, Telefonica	Pass	Drive tests conducted separately in the ES-PT CBC
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Pass	Network handover is managed by multi-SIM OBU and has been tested in both NSA mode to be used in ES-PT CBC
N11	The UEs can roam between MNO1 and MNO2		Partly	Only tested in lab in SA mode (yet to test roaming in NSA mode)
Logging related issues				
L1	Logging is in place for all components	AALTO	Pass	Implemented and tested for multi-SIM OBU
L2	Procedures for starting logging are in place	AALTO	Pass	Implemented and tested for multi-SIM OBU
L3	Logging formats comply with the agreed format	AALTO	Pass	Measurement data logged using DEKRA tool which has a format translatable to the CDF using a script provided by DEKRA
L4	Logged data can be uploaded to the CTS	AALTO	Partly	Test upload has been done to CTS but some updates where needed in the test data builder
L5	All data required is logged	AALTO	Pass	KPI data gathered in FI-TS tests and trials for remote driving
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)	AALTO	Pass	Validated in specific user story trials in FI-TS

6.6.5 Contribution of TS FR to CBC ES-PT: Multi SIM OBU Solution

Table 88: Checklist for the Multi SIM OBU solution from the FR trial site to the ES-PT CBC

ID	Issue	Partner(s)	Result	Explanation
Vehicle related issues				
V1	All CAVs are ready and available for the trials	VEDECOM	Pass	A connected vehicle is ready for the contribution.
V2	The physical components are integrated and operate correctly	VEDECOM	Pass	All the physical components, 5G OBU, Pepwave router etc. are integrated in the vehicle and operate correctly.
V3	The physical components, integrated in the vehicle, sent the correct information	VEDECOM	Pass	Yes, the 5G OBU send the correct information.
V4	The vehicle applications, including the automated driving applications, behave as expected and have been validated	VEDECOM	Pass	DEKRA application will be used for testing, and it behaves correctly.
V5	The vehicle applications are correctly installed	VEDECOM	Pass	Yes, applications, DEKRA and Pepwave, KPI agent, are correctly installed.
V6	The vehicle application has access to all required data in real time (e.g. vehicle data, sensor data) from other components.	VEDECOM	Pass	Yes, applications, particularly the KPI agent installed in the OBU has access to all required data, including GNSS, in real time.
V7	Messages and data content and encoding has been agreed between partners.	VEDECOM	Pass	DEKRA application server and agent will communicate with each other using TCP and UDP packets.
OBU related issues				
V10	All OBUs are ready and available for the trials	VEDECOM	Pass	Yes. Integrated in the vehicle.
V11	The OBUs are correctly installed in the CAV/CV	VEDECOM	Pass	Yes
V12	The applications in the OBU behave as expected and are validated	VEDECOM	Pass	Yes, the applications behave as expected.
V15	The OBUs connect and have access to the 5G network	VEDECOM	Partly	Tested in France; need to test in ES-PT.

ID	Issue	Partner(s)	Result	Explanation
V18	The OBUs allow for improved positioning (compared to GNSS positioning)		Pass	Vehicle has access to GNSS module.
V19	Synchronisation measures are used for the OBU		Partly	Synchronisation measures are tested in France. need to test in ES-PT
External servers				
S1	External servers and software, which are needed for the user story, are available		Pass	Data fusion server is available.
S2	External servers are connected to the network and accessible by all partners needing access		Partly	Data fusion server is tested in France and UK. It needs to be installed and tested at ES-PT CBC. Technical requirements are submitted to the ES-PT CBC.
S3	The applications on the external servers have been installed correctly and behave as expected and have been validated		Pass	Pepware fusion box and DEKRA server have been tested and behave correctly.
S4	Messages with the servers can be exchanged according to the relevant specifications		Pass	DEKRA server and agent will exchange data. The exchange has been tested.
S5	Synchronisation measures are used for the server		Partly	Tested in France; to be tested in ES-PT.
Network handover related issues				
N9	MNO1 can manage the connectivity handover procedures with MNO2		Partly	Works in France; to be tested in ES-PT
Logging related issues				
L1	Logging is in place for all components		Pass	The logging functions are developed and integrated in each component
L2	Procedures for starting logging are in place		Pass	Yes, KPI manager is in place
L3	Logging formats comply with the agreed format		Pass	Common data format, consequently, an updated version of CTS, is under revision in WP3 and WP5.
L4	Logged data can be uploaded to the CTS		Pass	Common data format, consequently, an updated version of CTS, is under revision in WP3 and WP5.
L5	All data required is logged		Not tested	Trials will be caried out at ES-PT.
L6	The validity of the timestamps in the logs has been verified (i.e. all devices are synchronised with each other)		Partly	Tested in France; need to test in ES-PT.