ETSI Plugtests Report V1.0.0 (2019-12)

1st ETSI C-V2X Plugtests
Malaga, Spain
02– 06 December 2019

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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Executive Summary

ETSI, in partnership with 5GAA, has organized the 1st C-V2X Plugtests™ interoperability events for C-V2X (Cellular Vehicle-to-Everything) using mobile communication technology for direct communication between vehicles, from vehicle to pedestrian and from vehicle to infrastructure. This event was hosted by DEKRA, from 02 to 06 December in Malaga, Spain. More than 300 test scenarios were executed between vendors and equipment, based on 3GPP Release-14.

Participating companies from the automotive sector tested the interoperability of their solutions. In addition they ran conformance tests with test equipment manufacturers to assess their compliance with ETSI ITS standards and 3GPP test specifications.

The 1st ETSI C-V2X Plugtests attracted a total of 17 vendors (full list below), with 70 participants on site, plus support from remote labs. Observers from different organizations witnessed the execution of more than 300 tests, based on a test plan with more than 38 test scenarios, with a 95 per cent success rate.

At this Plugtests event many C-ITS platforms demonstrated their interoperability by participating at state of the art safety use cases including road hazard signalling, road works warning, longitudinal collision risk warning and intersection collision risk warning.

ETSI 5GAA joint Plugtests event workshop was organized on 4th Dec 2019 in Malaga on C-V2X Interoperability and Deployment which was attended by 65 people . Prominent speakers from European Commission , Dutch Ministry of Infrastructure and Global Certification Forum presented latest updates on ITS deployment and certification.

The following equipment was tested:

C-V2X device vendors:

- BOSCH
- COMMSIGNIA
- FICOSA
- HUAWEI
- LGE
- NEUSOFT
- QUALCOMM
- SAVARI

PKI Providers:

- CRYPTA Labs
- GEMALTO (THALES)
- MICROSEC
- PENTA Security

Test Equipment Manufacturers:

- ANRITSU
- KEYSIGHT
- ROHDE & SCHWARZ
- SPIRENT

- SOFTWARE RADIO SYSTEMS

The Plugtests event was a pure testing event and no products were certified.

The next C-V2X Plugtests event is planned for H2 2020.

2 References

The following documents have been used as references in the Plugtests. The participants in the Plugtests agreed on a set of specific documents and versions for the second Plugtests. Please see also the test specification document for the references.

[1] ETSI TS 103 301 V1.1.1 (2016-11): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services".

[2] ETSI EN 302 636-4-1 (V1.4.0): "Intelligent Transport System (ITS); Vehicular communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to multipoint communications; Sub-part 1: Media independent functionalities".

[3] ETSI EN 302 637-2 (V1.4.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[4] ETSI EN 302 637-3 (V1.3.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

[5] ETSI EG 202 798 (V1.1.1): "Intelligent Transport Systems (ITS); Testing; Framework for conformance and interoperability testing".

[6] ETSI TS 101 556-1 (V1.1.1): "Intelligent Transport Systems (ITS); Infrastructure to Vehicle Communication; Electric Vehicle Charging Spot Notification Specification"

[7] ETSI TS 102 894-2 (V1.3.1): " Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary"

[8] ETSI EN 303 613 (V 1.1.1): “Intelligent Transport Systems (ITS); LTE-V2X Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band.

[9] ETSI TS 136 331 (V14.6.2): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification (3GPP TS 36.331 version 14.6.2 Release 14)".

[10] ETSI TS 136 321 (V14.7.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA);

[11] Medium Access Control (MAC) protocol specification (3GPP TS 36.321 version 14.7.0 Release 14)".

[12] ETSI TS 136 322 (V14.1.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification (3GPP TS 36.322 version 14.1.0 Release 14)".

[13] 5GAA Technical Report: "C-V2X Interoperability Test Plan for Mode 4 PC5".

[14] ETSI CTI Plugtests Guide For Lab Based Test Plan: "ETSI Lab Based Interoperability Test Plan".

[15] ETSI CTI Plugtests Guide For Field Based Test Plan: "ETSI Field Based Interoperability Test Plan ".

3 Abbreviations

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

3GPP	3rd Generation Partnership Project
AA	Authorization Authority
CA	Certification Authority
CAM	Cooperative Awareness Message
DENM	Decentralized Environmental Notification Message
DNS	Domain Name System
EUT	Equipment Under Test
GPSD	Daemon that receives data from a GPS receiver. It provides a unified interface to receivers of different types, and allows concurrent access by multiple applications
GN	GeoNetworking
HV	Host Vehicle
ICRW	Intersection Collision Risk Warning
ITS	Intelligent Transport System
ITS-S	ITS Station. Can be either RSU or OBU
LCRW	Longitudinal Collision Risk Warning
LTE	Long Term Evolution
MAC	Media Access Control layer of the access layers
NO	Test is recorded as NOT successfully passed
NA	Test is not applicable
NAT	Network address translation
OBU	On Board Unit
OK	Test is recorded as successfully passed
OT	Test is recorded as not being executed due to lack of time
PHY	The Physical layer of the access layers
PKI	Public Key Infrastructure
PSID	Provider Service Identifier
RSU	Road Side Unit
RWW	Road Works Warning
Test Session	A paring of vendors that test together during a given time slot
TRT	Test Reporting Tool
TSR	Test Session Report. Report created during a test session
V2V	Vehicle to Vehicle
V2X	Vehicle to Anything

4 Technical and Project Management

4.1 Scope

The main goal of the first C-V2X Plugtests was testing the interoperability of the V2X ecosystem. The 1st C-V2X Plugtests event enabled vendors to run interoperability test sessions to assess the level of interoperability of their implementation and validate the understanding of the standards. Different topics were addressed, including road hazard signaling, traffic sign violation and intersection collision risk warning. The ITS eco system was tested under real life conditions from infrastructure to applications in vehicles, thus demonstrating interoperability of C-V2X equipment.

4.2 Timeline

Registration to the C-V2X Plugtests event was open from 17th October 2019 to 15th November 2019 to any organisation willing to participate in testing the C-V2X Services Ecosystem. After registering to the C-V2X Plugtests event, participating organisations had to sign the Rules of Engagement (RoE) and Non-Disclosure Agreement (NDA) they received upon registration. Upon signature of the Rules of Engagement (RoE) and Non-Disclosure Agreement (NDA) sent to the official contact, the participants received their credentials for the C-V2X Plugtests WIKI and invitations to the preparation conference calls.

A total of 70 people were finally involved onsite in the face-to-face part of the Plugtests event plus remote labs.

The following clauses describe the different phases of the Plugtests event preparation. It is worth noting that since the start of the documentation phase until the first week of the face-to-face Plugtests event, weekly conference calls were run among organisers and participants to discuss and track the progress, anticipate and solve technical issues, review the test plan, etc.

4.3 Test Scheduling

The preliminary test schedule was developed before the Plugtests event and was circulated to all the participants in advance for comments. ETSI test reporting tool was used to schedule the test session between all the devices. OBU vendors rented test vehicle in which the OBU was installed. The test schedule allowed for each OBU vendor to test against all OBUs and field RSU. Each day was organized in a morning test session from 9.00 to 12.45 and in an afternoon test session from 14.00 to 18.00.

During the test event the test schedule was constantly updated according to the progress of the test sessions. This was done during the daily wrap-up meetings at the end of each day and during face-to-face meetings with the participants.

4.3.1 Documentation

Once the registration to the Plugtests event was closed, the following documentation activities were launched in parallel:

1) EUT Documentation

Participants documented their EUTs, by providing the information directly to the Plugtests event team. The Plugtests event team compiled the final EUT table for all the participating vendors and was appended to the Plugtests event Test Plan,

All the information described above was made available in the Plugtests event WIKI, so that it could be easily maintained and consumed by participants.

2) Test Plan Development

The Test Plan development was led by ETSI Centre for Testing and Interoperability following the methodology defined by 3GPP TSGs and ETSI TC ITS. The Test Plan was scoped around 3GPP Test Specification Release-14 capabilities and concentrated on the features supported by the implementations attending the Plugtests event.

The Test Plan was developed and consolidated in an iterative way, taking into account input and feedback received from Plugtests event participants. See details in clause 8.

4.3.2 Plugtests event

From 2nd of December to the 6th of December 2019, participants sent representatives to the host premises in DEKRA, Malaga to collaboratively run the Interoperability Test Sessions. The Plugtests were kindly hosted by the DEKRA at their facilities in Malaga, Spain.

This one-week on-site face-to-face event was scheduled as follows:

CV2X PLU Agenda (2-6 December 2019)					
Time	Monday 2	Tuesday 3	Wednesday 4	Thursday 5	Friday 6
08:30	Room Opening	Room Opening	Room Opening	Room Opening	Room Opening
09:00 10:45	SET-UP / WELCOME PRESENTATION	TEST SESSION #4	TEST SESSION #7 + WORKSHOP	TEST SESSION #10	TEST SESSION #13
10:45 12:00	TEST SESSION #1				
12:00 12:30					FINAL WRAP-UP
13:30 14:25	LUNCH BREAK - BUS 2	LUNCH BREAK - BUS 2	LUNCH BREAK - 12.30 to 14.00	LUNCH BREAK - BUS 2	TEAR-DOWN AND SANDWICHES - starts at 12.30
14:00 16:00	TEST SESSION #2	TEST SESSION #5	TEST SESSION #8 + INTEROP DEMO for WORKSHOP ATTENDEES 2 to 3.15pm	TEST SESSION #11	Bus leaves at 2pm
16:00 17:55	TEST SESSION #3 + Wrap Up Session at 17:40	TEST SESSION #6 + Wrap Up Session at 17:40	TEST SESSION #9 + Wrap Up Session at 17:40	TEST SESSION #12 + Wrap Up Session at 17:40	
	bus leaves at 6pm	Bus leaves at 6pm - short visit of the city center - social event starts at 7.45pm	bus leaves at 6pm	bus leaves at 6pm	

Figure 1. High-level schedule for Plugtests event on-site

First half of Monday was dedicated to local installation and pre-testing continuation, this time also including local implementations. A number of EUTs were installed and connected locally to the IT infrastructure, as well as some test and support functions.

The following 5 days were dedicated to on-site interoperability test sessions involving all the participating EUTs organised in several parallel tracks.

The scheduling of individual test combinations was done dynamically using ETSI Test reporting tool with the inputs and requests from the participants. The schedule was adapted during the test session slots on a per need basis.

4.4 Tools

4.4.1 Plugtests event WIKI

The Plugtests event WIKI was the main source of information for the C-V2XPlugtests event, from logistics aspects to testing procedures. Access to the WIKI was restricted to participating companies.

The main technical information provided in the wiki was organised as follows:

- **Event Information** – Logistics aspects of the Plugtests event.
- **Participants** – Name of the participants of the Plugtests event.
- **News** – Press Releases of the Plugtests event.
- **Network Information** – IT Network Infrastructure of the Plugtests event.
- **Testing Information –** Important Information for EUTs Testing.
- **Test Plan –** Test Plans used for EUTs Testing.

- **Test Reporting Tool** - Documentation of the Test Reporting Tool.
- **Equipment Registration** - Participating EUTs overview.
- **PKI Information –** Security certificates provided by PKI vendors.
- **Conference Calls** - Calendar, logistics, agendas and minutes of the weekly conference calls run during the remote integration and pre-testing phase.
- **Social Event** – Social event details.

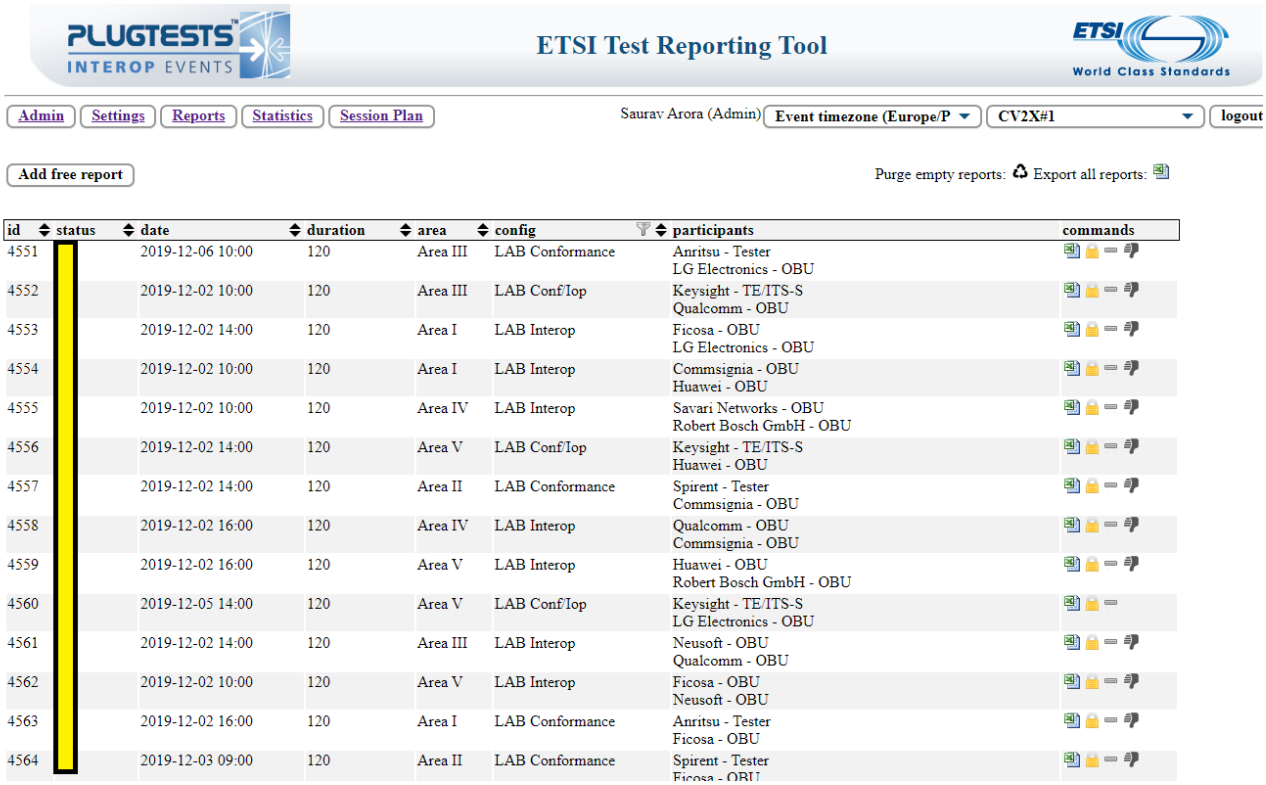
In addition, the embedded WIKI Chat and Slack was used among the participants to communicate with each other during the pre-testing phase and Test Sessions, include their remote colleagues (back-office support) in the discussions.

4.4.2 Test Reporting Tool (TRT)

The Test Reporting Tool guides participants through the Test Plan test cases during the on-site Test Sessions. It allows creating Test Session Reports compiling detailed results for the individual scheduled Test Sessions.

Only the companies providing the EUTs for each specific Test Session combination have access to their Test Session Reports contents and specific results. All companies involved in a specific session and who have entered the test results were required to verify and approve the reported results at the end of each session. Only test report which has been approved by all involved parties are considered as valid.

Another interesting feature of this tool is the ability to generate real-time stats (aggregated data) of the reported results, per test case, test group, test session or overall results. These stats are available to all participants and organisers and allow tracking the progress of the testing with different levels of granularity, which is extremely useful to analyse the results.



id	status	date	duration	area	config	participants	commands
4551		2019-12-06 10:00	120	Area III	LAB Conformance	Anritsu - Tester LG Electronics - OBU	
4552		2019-12-02 10:00	120	Area III	LAB Conf/Iop	Keysight - TE/ITS-S Qualcomm - OBU	
4553		2019-12-02 14:00	120	Area I	LAB Interop	Ficosa - OBU LG Electronics - OBU	
4554		2019-12-02 10:00	120	Area I	LAB Interop	Commsignia - OBU Huawei - OBU	
4555		2019-12-02 10:00	120	Area IV	LAB Interop	Savari Networks - OBU Robert Bosch GmbH - OBU	
4556		2019-12-02 14:00	120	Area V	LAB Conf/Iop	Keysight - TE/ITS-S Huawei - OBU	
4557		2019-12-02 14:00	120	Area II	LAB Conformance	Spirent - Tester Commsignia - OBU	
4558		2019-12-02 16:00	120	Area IV	LAB Interop	Qualcomm - OBU Commsignia - OBU	
4559		2019-12-02 16:00	120	Area V	LAB Interop	Huawei - OBU Robert Bosch GmbH - OBU	
4560		2019-12-05 14:00	120	Area V	LAB Conf/Iop	Keysight - TE/ITS-S LG Electronics - OBU	
4561		2019-12-02 14:00	120	Area III	LAB Interop	Neusoft - OBU Qualcomm - OBU	
4562		2019-12-02 10:00	120	Area V	LAB Interop	Ficosa - OBU Neusoft - OBU	
4563		2019-12-02 16:00	120	Area I	LAB Conformance	Anritsu - Tester Ficosa - OBU	
4564		2019-12-03 09:00	120	Area II	LAB Conformance	Spirent - Tester Ficosa - OBU	

Figure 2. Test Reporting Tool – example screen shot

5 Equipment Under Test

The tables below summarise the different EUTs provided by the Plugtests event participants:

5.1 C-V2X device vendors

Organisation	Comment
BOSCH	–
COMMSIGNIA	–
HUAWEI	–
LGE	–
NEUSOFT	–
QUALCOMM	–
SAVARI	–

Table 1. On Board Units Under Test

5.2 PKI providers

Organisation	Comment
CRYPTA Labs	–
GEMALTO (THALES)	–
MICROSEC	–
PENTA Security	–

Table 2. PKI Under Test

5.3 Test Equipment Manufacturers

Organisation	Comment
ANRITSU	–
KEYSIGHT	–
ROHDE & SCHWARZ	–
SPIRENT	–
SOFTWARE RADIO SYSTEMS	–

Table 3. Test Equipment Manufacturers Under Test

6 Test Infrastructure

6.1 Local Test Infrastructure

The face to face testing phase were enabled by the setup as shown in Figure 5:

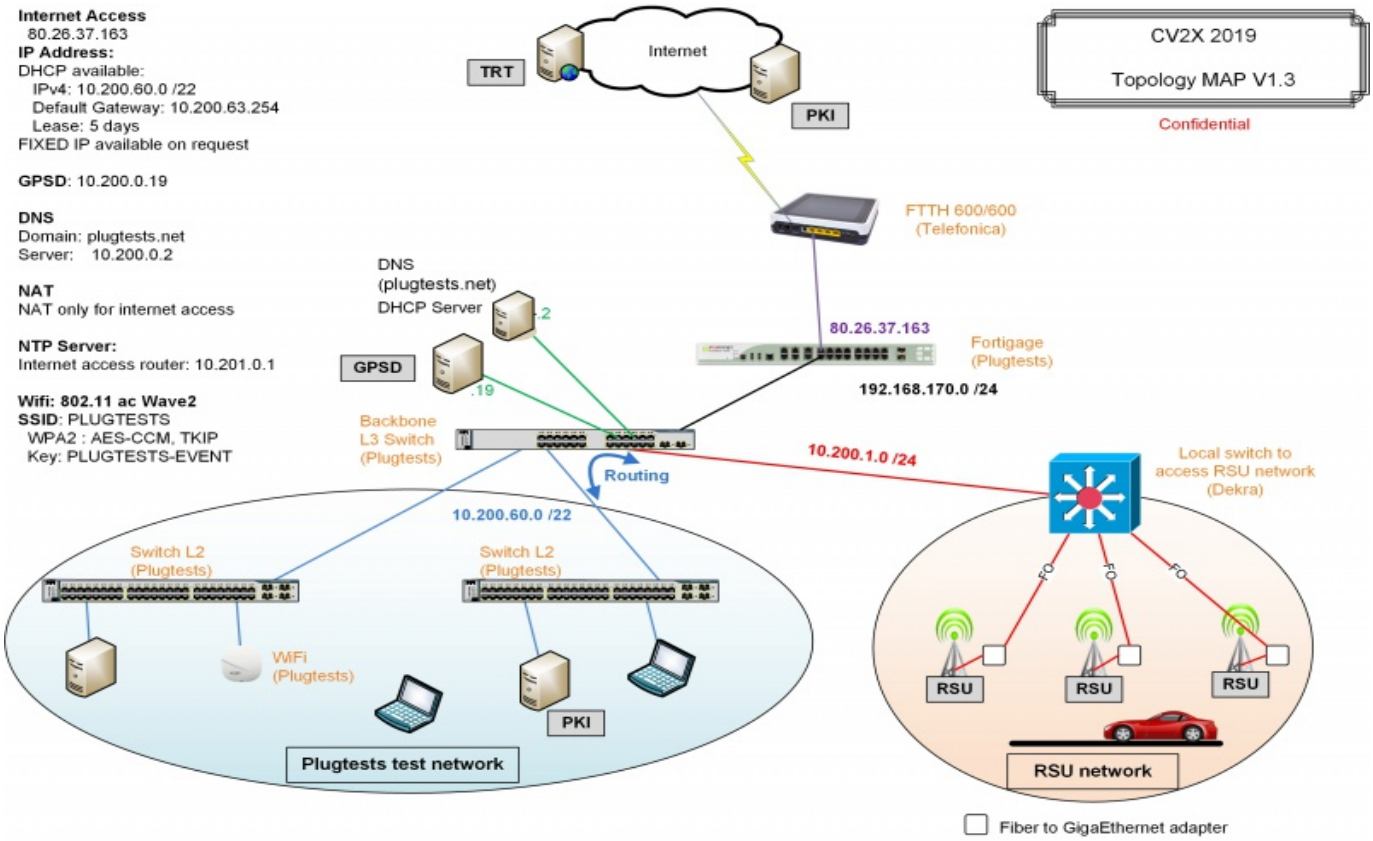


Figure 3. Local Test Infrastructure

6.2 Local Outdoor Infrastructure for Field Testing

The face to face event included lab as well field testing on the test track. Field interoperability testing included road hazard signalling, road works warning, longitudinal collision risk warning and intersection collision risk warning.

The different field interoperability testing use cases were performed in different places along the test track, with no overlapping among the different places in order to ensure participants safety.

For uses cases related with road hazard signalling and road works warning, some signalling cones were deployed along the test track in order to ease that warnings were provided at the right place.

Participants brought their own cars where their devices were installed in order to perform such a field testing.

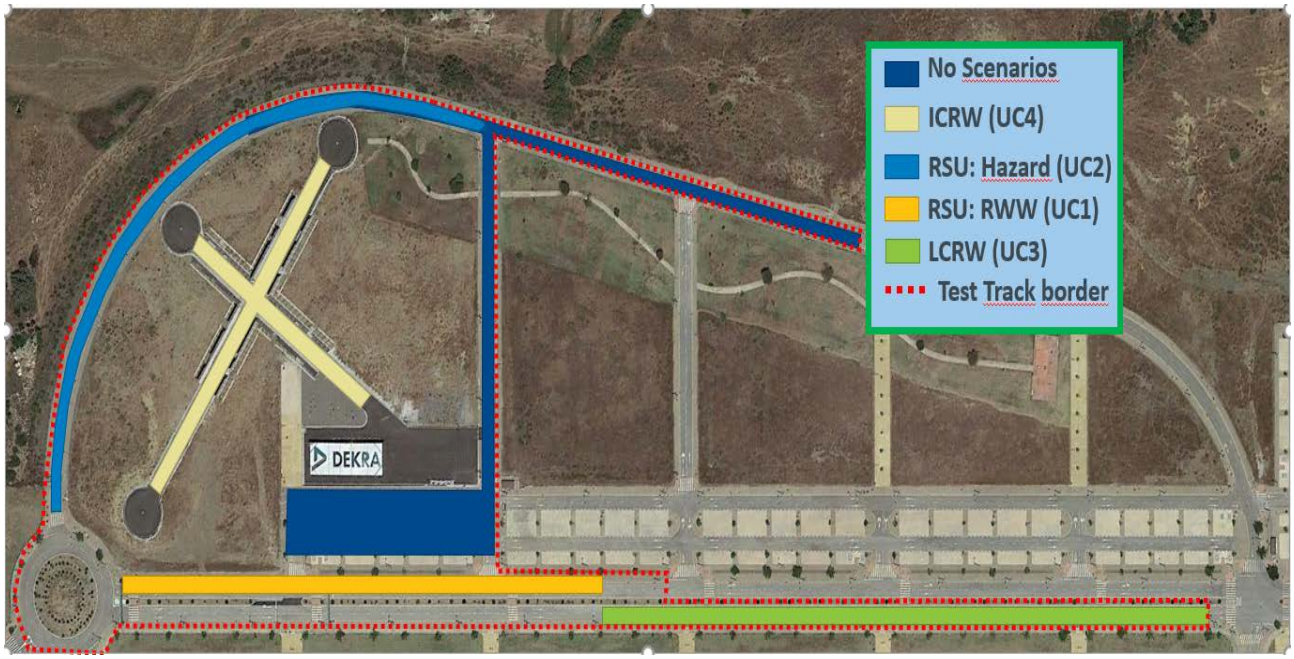


Figure 4. Outdoor Plan

6.3 GPSD Server Configuration

The GPSD server emulated the movement of cars on the test track. It provided different positions for each vendor in order to avoid position collisions. All positions and port allocations were presented at the GPSD server web interface. The GPSD server was synchronized with the local NTP server on time.windows.com.

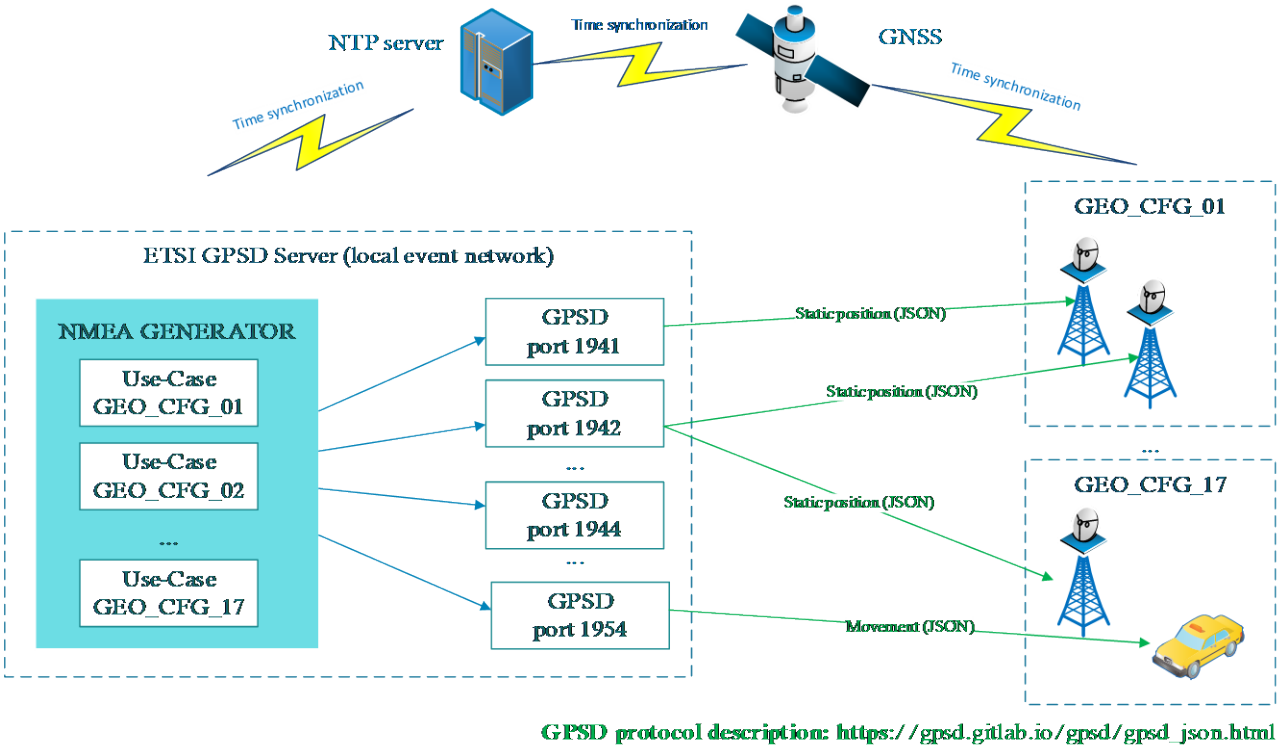


Figure 5a. GPSD Server Configuration

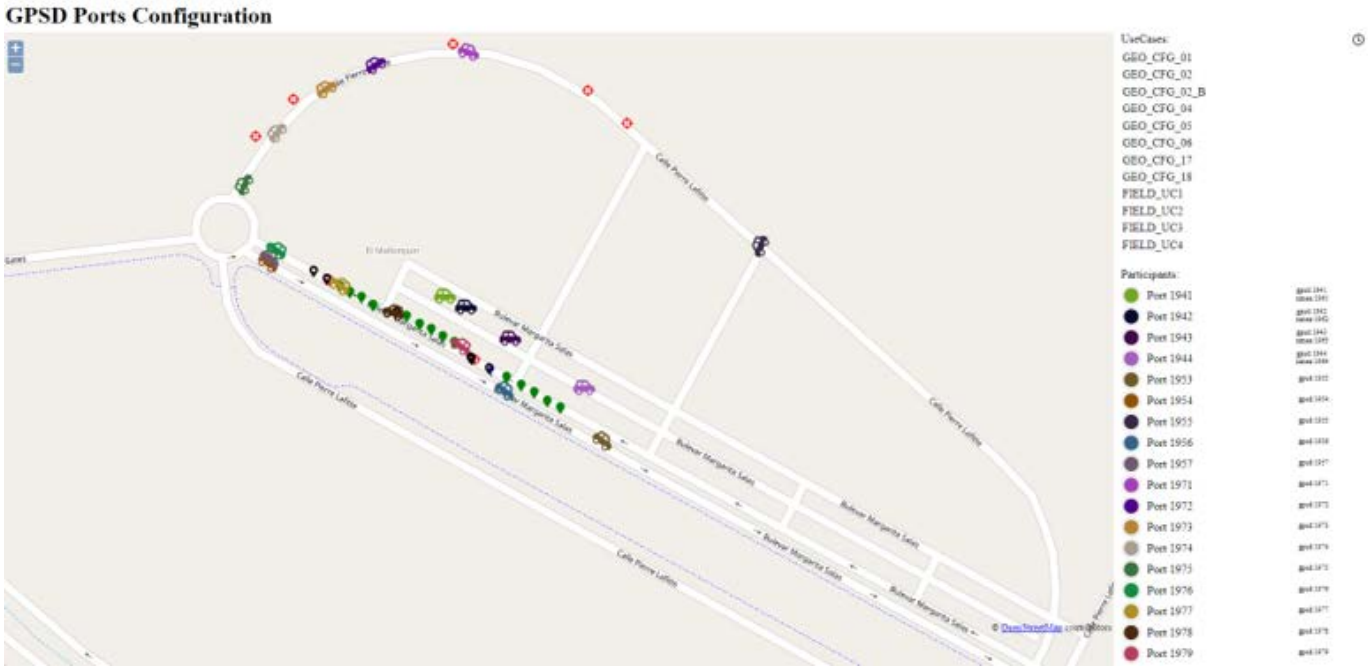


Figure 5b. GPSD Web Interface

6.4 Kinematic Server Configuration

The main function of such a server was to convert GPSD data format into a different format for devices not supporting gpsd but kinematics clients. As shown in the figure below, Kinematics proxy consisted of a GPSD client, that took timing and positioning from the above mentioned gpsd server, and a kinematics server, that provided such a positioning and timing information to the different kinematics clients.

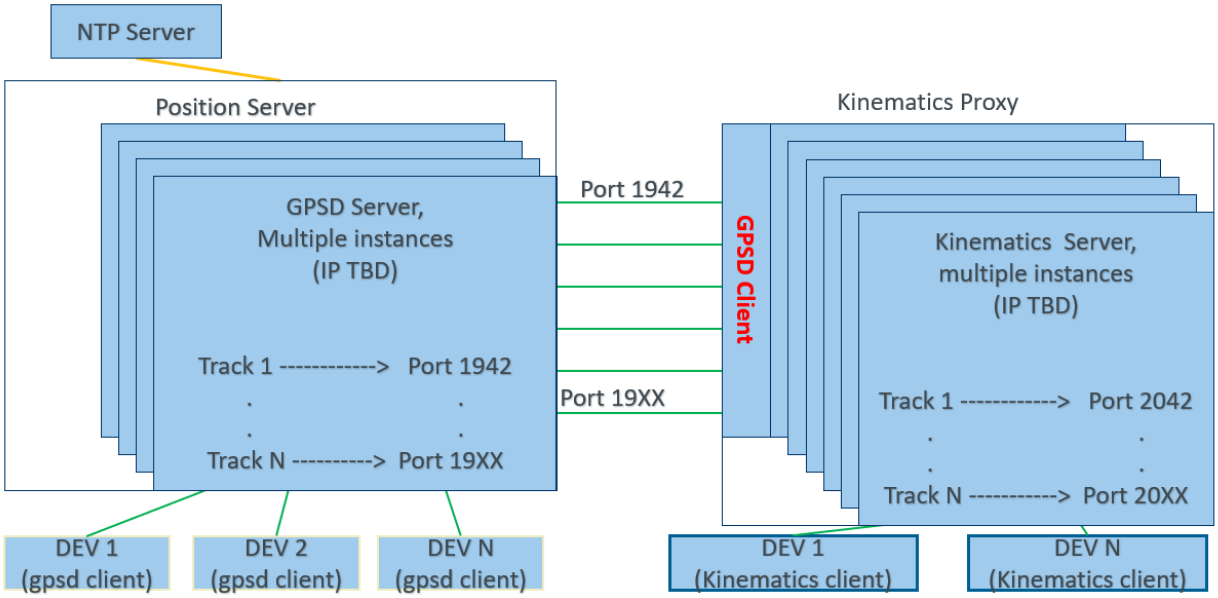


Figure 6. Kinematic Server Configuration

7 Test Procedures

7.1 Interoperability Testing Procedure

During the on-site face-to-face part of the Plugtests event, a daily Test Session Schedule was produced and shared via the WIKI. Test Sessions were organised in several parallel tracks, ensuring that all participants had at least one Test Session scheduled any time. The different test configurations were used for the main event.

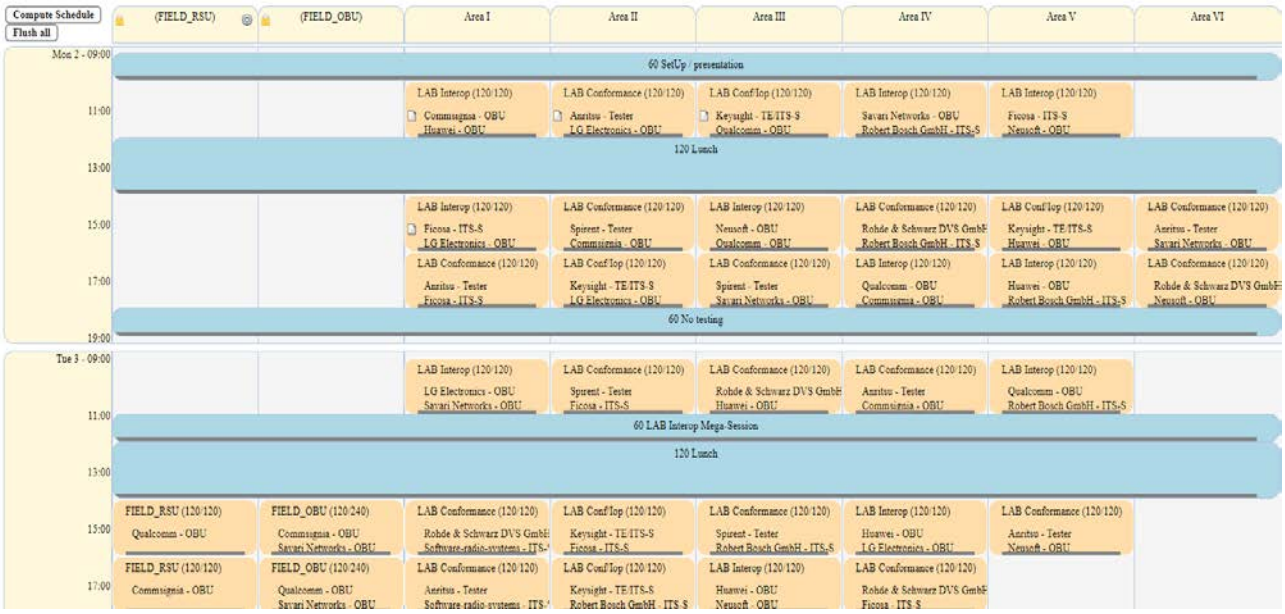


Figure 7. Daily Schedule & Test Sessions – example excerpt

Config Name	Main Test Configuration
FIELD_OBU	ITS-S + ITS-S
FIELD_RSU	ITS-S + Simulated RSU on Field
LAB Conf/Iop	ITS-S + Tester (ITS-S)
LAB Conformance	ITS-S + Tester
LAB Interop	ITS-S + ITS-S

Table 4. Main Test Configurations

During each test session, for each tested combinations the Interoperability testing procedure was as follows:

1. The participating vendors opened the Test Session Report and the Test Plan.

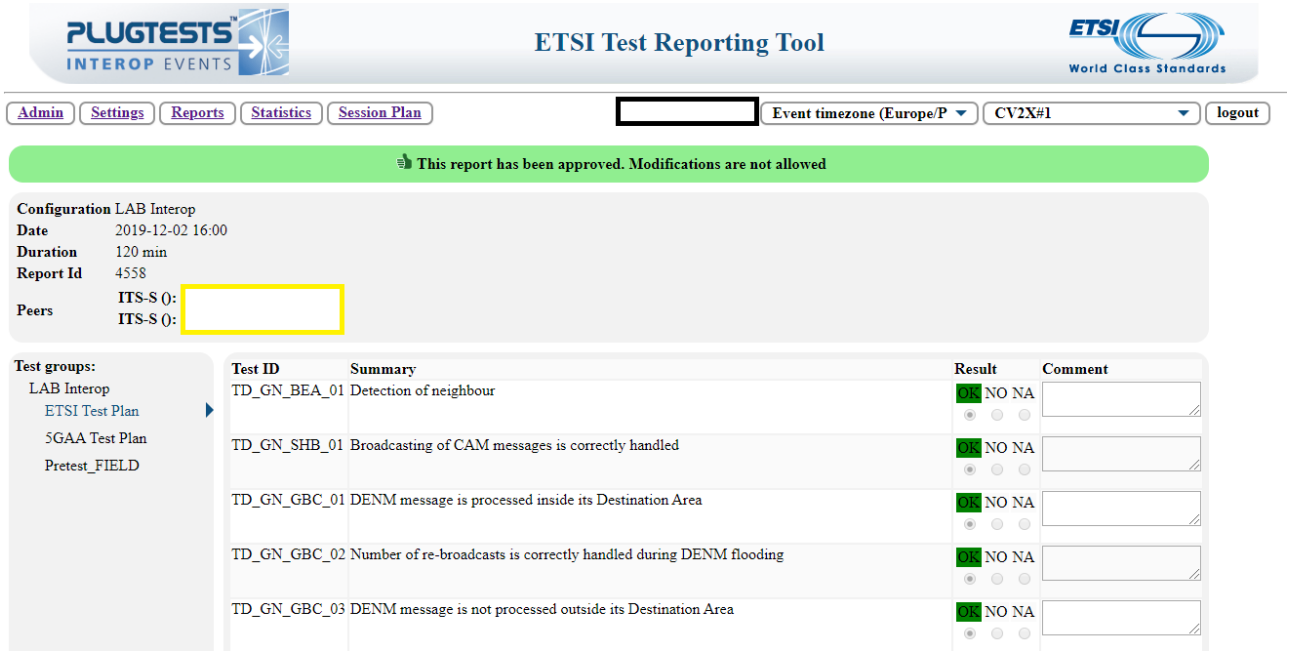


Figure 8. Test Session Report example excerpt

2. For each Test in the Test Plan:

   a. The corresponding Test Description and EUT Configuration were followed for Road works Warning

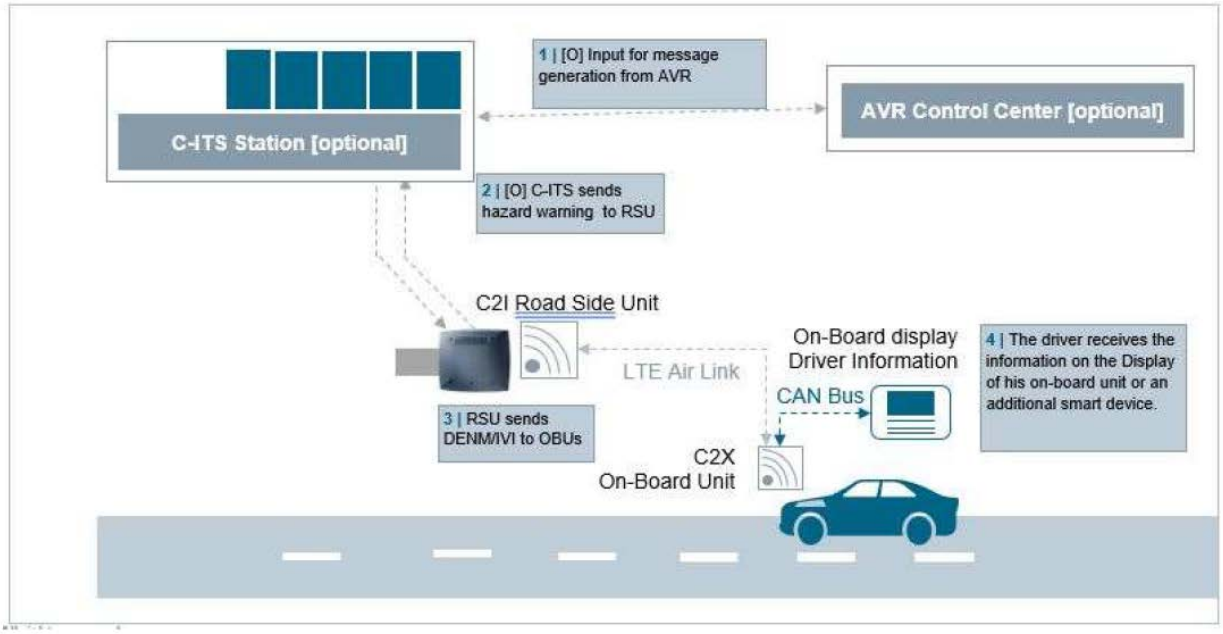


Figure 9a. System Under Test (SUT) Configuration – Road Works Warning example excerpt

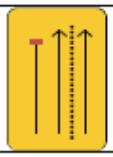
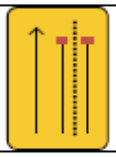
Interoperability Test Description				
Identifier:	TD_ITS_UC01_01			
Objective:	Process RWW Information			
Configuration:	See Figure 2			
Pre-test conditions:	• HV is outside the relevance area • A single RSU broadcasts RWW DENMs D1, D2 and D3 (pre-configured or via TCC) • HV receives RWW DENMs D1, D2 and D3			
Test Sequence:	**Step**	**Type**	**Description**	**HMI**
	1	stimulus	HV enters the use case zone on the test track	
	2	stimulus	HV enters the Relevance Area and synchronizes to the trace of D1	
	3	verify	HMI displays the speed limit before POS0	
	4	verify	HMI displays the closed lane information before POS1	
	5	stimulus	HV synchronizes to the trace of D2	
	6	verify	HMI displays the closed lane information before POS2	
	7	stimulus	HV synchronizes to the trace of D3	
	8	verify	HMI displays the closed lane information before POS3	
	9	verify	HMI shows no more closed lane information and end of speed limitation	

Figure 9b. Road Works Warning example excerpt

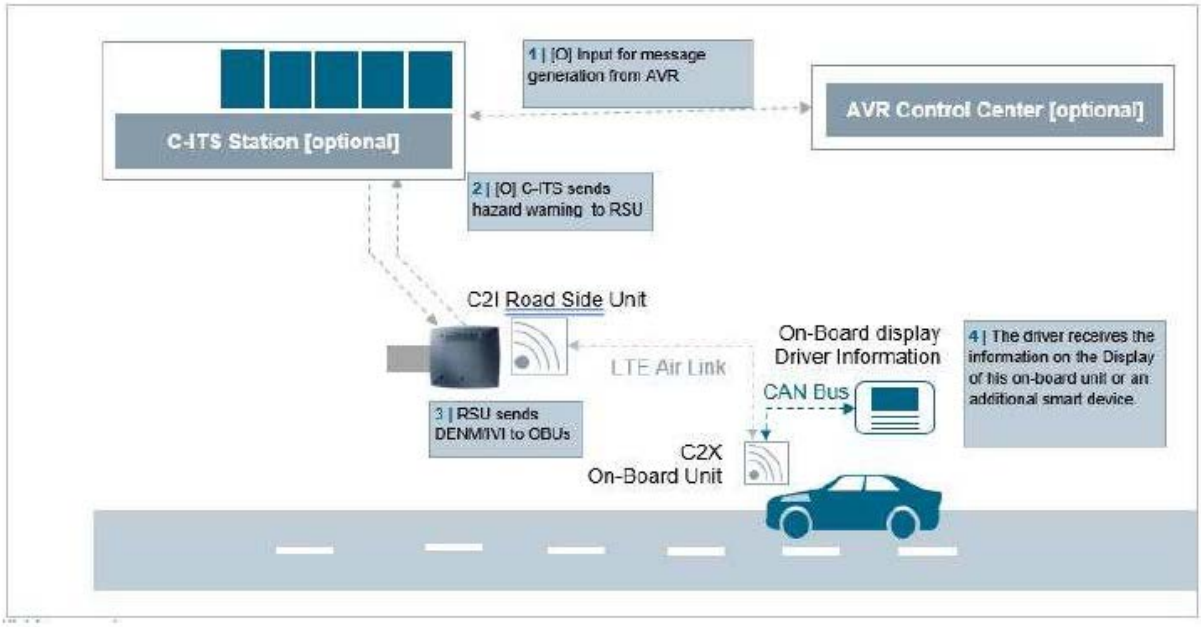


Figure 10a. System Under Test (SUT) Configuration – Hazards on the road example excerpt

Interoperability Test Description				
Identifier:	TD_ITS_UC02_02			
Objective:	Process Hazard on the Road Warning (HRW) Information (Adverse weather condition - extreme weather condition)			
Configuration:	See Figure 4			
Pre-test conditions:	• HV is outside the relevance area			
Test Sequence:	**Step**	**Type**	**Description**	**HMI**
	1	stimulus	HV enters the use case zone on the test track	
	3	verify	RSU broadcasts D1	
	4	stimulus	HV enters the Relevance Area	
	5	verify	HMI displays the Hazard on the Road Warning	

Figure 10b. Hazards on the road example

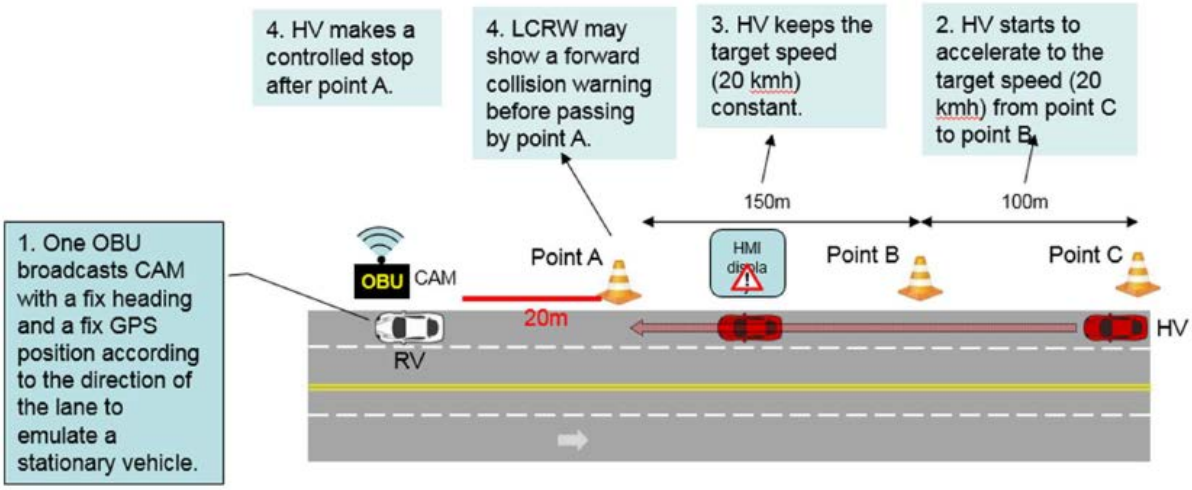


Figure 11a. System Under Test (SUT) Configuration – Longitudinal Collision Risk Warning example

Interoperability Test Description				
Identifier:	TD_ITS_UC03_01			
Objective:	Verify longitudinal collision risk warning use case			
Configuration:	See Figure 17			
Pre-test conditions:	• HV is running LCRW • RV is stationary and sends CAMs • HV is accelerating to TARGET_SPEED between points C and B			
Test Sequence:	**Step**	**Type**	**Description**	**HMI**
	1	stimulus	HV passes point B	
	2	verify	HMI indicates a forward collision risk before point A	Forward collision

Figure 11b. Longitudinal Collision Risk Warning example excerpt

3. C-V2X equipment providers jointly executed the different steps specified in the test description and evaluated interoperability through the different IOP Checks prescribed in the Test Description

b. The C-V2X equipment provider recorded the Test Result in the Test Session Report, as follows:

i. OK: all IOP Checks were successful

ii. NOK: at least one IOP Check failed. A comment was requested.

iii. NA: the feature was not supported by at least 1 of the involved EUTs. A comment was requested.

4. Once all the tests in the Test Session Report were executed and results recorded, the participants reviewed the Report and approved it.

8 Test Plan Overview

8.1 Introduction

This 1st C-V2X Plugtests Test Plan was developed following ETSI guidelines for interoperability. It is based on the test plan from the previous ITS Plugtests. There were four different test plans available for testing which are attached with the report.

- 5GAA C-V2X lab-based Interoperability Test Plan for Mode 4 PC5 [13].
- ETSI Lab Based Interoperability Test Plan for CAM/DENM/GEONETWORKING [14].
- ETSI Field Based Interoperability Test Plan for CAM and DENM Scenarios [15].
- Conformance and RF test plan offered by TE vendors.

The Test Plan was reviewed and discussed with participants during the preparation and pre-testing phase. Considering the huge number of resulting test cases and difference expected maturity of the implementations.

8.2 Group of test cases

As described in the Subclause 4.1 of this document, different test objectives were considered. Please refer to test plans attached with the report.

The following tables collect the test cases grouped by test objective following the structure of the test specification document itself.

Test Id	Test Purpose
TD_ITS_UC01_01	Road Works Warning
TD_ITS_UC02_01	Process Hazard on the Road Warning (HRW) Information (Accident)
TD_ITS_UC02_02	Process Hazard on the Road Warning (HRW) Information (Adverse weather condition - extreme weather condition)
TD_ITS_UC02_03	Process Hazard on the Road Warning (HRW) Information (Human presence on the road)
TD_ITS_UC02_04	Process Hazard on the Road Warning (HRW) Information (Stationary vehicle)
TD_ITS_UC02_05	Process Hazard on the Road Warning (HRW) Information (Emergency vehicle approaching)
TD_ITS_UC02_06	Process Hazard on the Road Warning (HRW) Information (Hazardous location - Obstacle on the road)
TD_ITS_UC02_07	Process Hazard on the Road Warning (HRW) Information (Signal violation)

Table 5. Test Group for the ETSI Field Based Interoperability Test Plan [15]

Test Id	Test Purpose
TD_GN_BEA_01	Detection of neighbour
TD_GN_SHB_01	Broadcasting of CAM messages is correctly handled
TD_GN_GBC_01	DENM message is processed inside its Destination Area
TD_GN_GBC_02	Number of re-broadcasts is correctly handled during DENM flooding
TD_GN_GBC_03	DENM message is not processed outside its Destination Area
TD_GN_GBC_04	Geo-broadcast message caching is correctly implemented
TD_CAM_05	CAM messages and their mandatory data elements are

Test Id	Test Purpose
	interoperable
TD_CAM_08	CAM generation frequency of stationary vehicle is T_GenCamMax
TD_CAM_09	CAM generation interval equals T_GenCam_Dcc while position difference with respect to previous CAM exceeds 4 m (speed is constant)
TD_CAM_10	CAM generation frequency corresponds to the position difference based dynamic trigger
TD_CAM_11	CAM generation interval equals T_GenCam_Dcc while speed difference with respect to previous CAM exceeds 0.5 m/s (acceleration is constant)
TD_CAM_12	CAM generation frequency corresponds to the speed difference based dynamic trigger
TD_DENM_01	DENM re-transmissions are correctly received within the DENM lifetime
TD_DENM_02	DENM re-transmissions are not received after the DENM lifetime

Table 6. Test Group for the ETSI Lab Based Interoperability Test Plan [14]

Test Id	Test Purpose
TD_5GAA_1	This test verifies that the devices under test can transmit and receive C-V2X messages (one semi-persistent scheduling (SPS) flow with 100 ms periodicity) over PC5 interface.
TD_5GAA_2	This test verifies that the devices under test can transmit and receive C-V2X messages (two SPS flows each with 100 ms periodicity) over PC5 interface.
TD_5GAA_3	This test verifies that the devices under test can transmit and receive C-V2X messages (two SPS flows each with 100 ms periodicity and multiple event-driven flows) over PC5 interface.
TD_5GAA_4	This test verifies that the devices under test can transmit and receive C-V2X messages (two SPS flows each with 100 ms periodicity, IP-based and multiple event-driven flows non-IP) over PC5 interface.
TD_5GAA_5	This test verifies that the devices under test can transmit and receive C-V2X messages (two SPS flows with 20 ms and 50 ms periodicity) over PC5 interface.
TD_5GAA_6	This test verifies that the devices under test can transmit and receive C-V2X messages (two SPS flows with 20 ms and 50 ms periodicity and multiple event-driven flow with varying payloads) over PC5 interface.
TD_5GAA_8	This test verifies that the devices under test, the transmitter can transmit using one Tx pool (two SPS flows each with 100 ms periodicity) and the receiver can receive C-V2X messages on the corresponding Rx pool over PC5 interface when the receiver is configured with four Rx pools that overlap in SF bitmap, non-overlapping RBs.
TD_5GAA_9	This test verifies that the devices under test, the transmitter can transmit using one Tx pool (two SPS flows each with 100 ms periodicity) and the receiver can receive C-V2X messages on the corresponding Rx pool over PC5 interface when the receiver is configured with four Rx pools that overlap in SF bitmap, non-overlapping RBs.
TD_5GAA_10	This test verifies that the transmit device changes its source address after T5000 timer expiry, the receiver should be able to receive all the transmissions from the transmitter and pass it to the higher layers.
TD_5GAA_11	This test verifies that the devices under test can transmit and receive C-V2X messages (two SPS flows each with 100 ms periodicity, each SPS flow corresponding to a Tx pool) over PC5 interface.
TD_5GAA_12	This test verifies that the devices under test can transmit and receive C-V2X messages (SPS flow with 100 ms periodicity) over

Test Id	Test Purpose
	PC5 interface in presence of congestion.
TD_5GAA_13	This test verifies that the devices under test can transmit and receive C-V2X traffic information message (TIM) (or) equivalent message, depending on the region that is being tested (event-driven flows with 1000 ms periodicity) over PC5 interface.
TD_5GAA_14	This test verifies that the devices under test can transmit and receive C-V2X SPAT (or) equivalent message, depending on the region that is being tested (one SPS flow each with 100 ms periodicity) over PC5 interface.
TD_5GAA_15	This test verifies that the devices under test can transmit and receive C-V2X MAP (or) equivalent messages depending on the region that is being tested (event-driven flows with 1000 ms periodicity) over PC5 interface.

Table 7. Test Group for the 5GAA C-V2X lab based Interoperability Test Plan for Mode 4 PC5 [13].

9 Interoperability Results

9.1 Overall Results

During the face to face Plugtests event at Dekra, 334 test executions were conducted, and interoperability results were reported in the Test reporting tool.

The table below provides the overall results (aggregated data) from all the Test Cases run during all the Test Sessions with all the different combinations of Equipment Under Test from all the participating companies.

Among the executed Test Cases, the possible results were “OK”, when interoperability was successfully achieved and “NO” (Not OK) when it was not.

Interoperability		**Totals**
OK	**NO**	**Run**
318 (95.2%)	16(4.8%)	334

Table 8. Overall Results

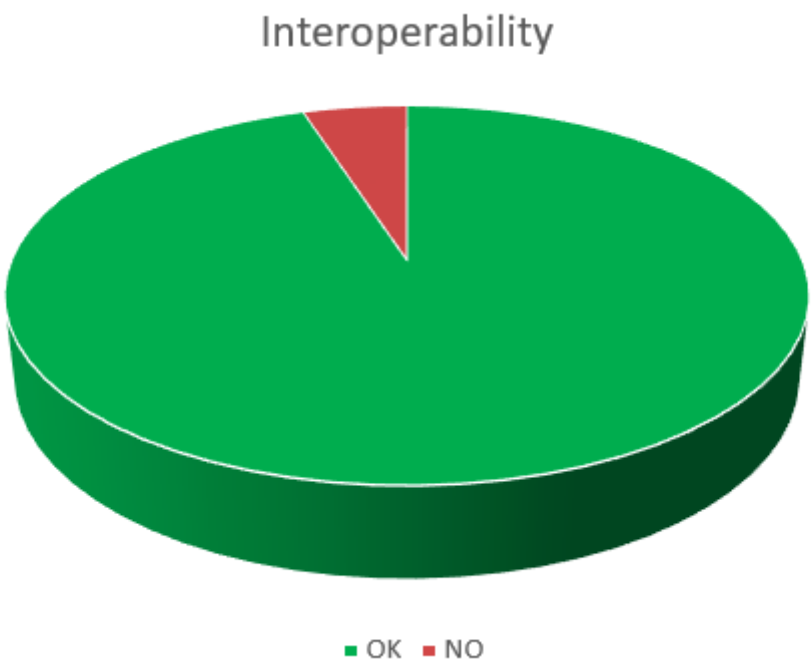


Figure 12. Overall results (%)

An overall interoperability success rate of 95% was achieved, which indicates a very high degree of compatibility among the participating implementations (EUTs) in the areas of the Test Plan where features were widely supported and the test cases could be executed in most of the Test Sessions. In the next clauses, we will see that this high rate is also a consequence of the good preparation and involvement of participants during the preparation phase of the Plugtests.

9.3 Results per Group

The table below provides the results for each test configuration in the scope of the Plugtests event.

Configuration	Interoperability		Total
	OK	NO	Run
FIELD_RSU	8 (50.0%)	8 (50.0%)	16
FIELD_OBU	6 (100.0%)	0 (0.0%)	6
ETSI Test Plan	148 (96.7%)	5 (3.3%)	153
5GAA Test Plan	65 (100.0%)	0 (0.0%)	65
Pretest_FIELD	0 (0.0%)	0 (0.0%)	0
LAB Conf/Iop	91 (96.8%)	3 (3.2%)	94

Table 9. Results per Group

9.3 Results per Test Case

The table below provides the results for each test case in the scope of the Plugtests event.

	Interoperability		Total
	OK	NO	Results
TD_GN_BEA_01	17 (100.0%)	0 (0.0%)	17
TD_GN_SHB_01	26 (100.0%)	0 (0.0%)	26
TD_GN_GBC_01	19 (100.0%)	0 (0.0%)	19
TD_GN_GBC_02	5 (100.0%)	0 (0.0%)	5
TD_GN_GBC_03	17 (100.0%)	0 (0.0%)	17
TD_GN_GBC_04	4 (100.0%)	0 (0.0%)	4
TD_CAM_05	25 (100.0%)	0 (0.0%)	25
TD_CAM_08	20 (100.0%)	0 (0.0%)	20
TD_CAM_09	18 (94.7%)	1 (5.3%)	19
TD_CAM_10	13 (81.3%)	3 (18.8%)	16
TD_CAM_11	16 (94.1%)	1 (5.9%)	17
TD_CAM_12	11 (78.6%)	3 (21.4%)	14
TD_DENM_01	3 (100.0%)	0 (0.0%)	3
TD_DENM_02	1 (100.0%)	0 (0.0%)	1
TD_5GAA_1	15 (100.0%)	0 (0.0%)	15
TD_5GAA_2	15 (100.0%)	0 (0.0%)	15
TD_5GAA_3	12 (100.0%)	0 (0.0%)	12
TD_5GAA_4	5 (100.0%)	0 (0.0%)	5
TD_5GAA_5	11 (100.0%)	0 (0.0%)	11
TD_5GAA_6	11 (100.0%)	0 (0.0%)	11
TD_5GAA_8	0 (0.0%)	0 (0.0%)	0
TD_5GAA_9	0 (0.0%)	0 (0.0%)	0
TD_5GAA_10	1 (100.0%)	0 (0.0%)	1
TD_5GAA_11	1 (100.0%)	0 (0.0%)	1
TD_5GAA_12	3 (100.0%)	0 (0.0%)	3
TD_5GAA_13	8 (100.0%)	0 (0.0%)	8
TD_5GAA_14	8 (100.0%)	0 (0.0%)	8
TD_5GAA_15	3 (100.0%)	0 (0.0%)	3
TD_ITS_UC01_01	3 (75.0%)	1 (25.0%)	4
TD_ITS_UC02_01	3 (75.0%)	1 (25.0%)	4
TD_ITS_UC03_01	5 (100.0%)	0 (0.0%)	5
TD_ITS_UC04_01	5 (100.0%)	0 (0.0%)	5
TD_ITS_UC02_02	4 (80.0%)	1 (20.0%)	5

TD_ITS_UC02_03	3 (75.0%)	1 (25.0%)	4
TD_ITS_UC02_04	2 (66.7%)	1 (33.3%)	3
TD_ITS_UC02_05	2 (66.7%)	1 (33.3%)	3
TD_ITS_UC02_06	1 (50.0%)	1 (50.0%)	2
TD_ITS_UC02_07	1 (50.0%)	1 (50.0%)	2

Table 10. Results per Test Case

9.4 Overall Conformance Testing Result

During the face to face Plugtests event at Dekra, 204 test scenarios were conducted, and conformance test results were reported by the TE vendors.

The table below provides the overall results (aggregated data) from all the Test Cases run during all the Test Sessions with all the different combinations of Equipment Under Test from all the participating companies.

Among the executed Test Cases, the possible results were “OK”, when conformance was successfully achieved and “NO” (Not OK) when it was not.

Note: Please contact relevant TE vendors for more details on test cases offered for the conformance testing.

Conformance		Totals
OK	**NO**	**Run**
186 (91.17%)	18(8.83%)	204

Table 11. Overall Results

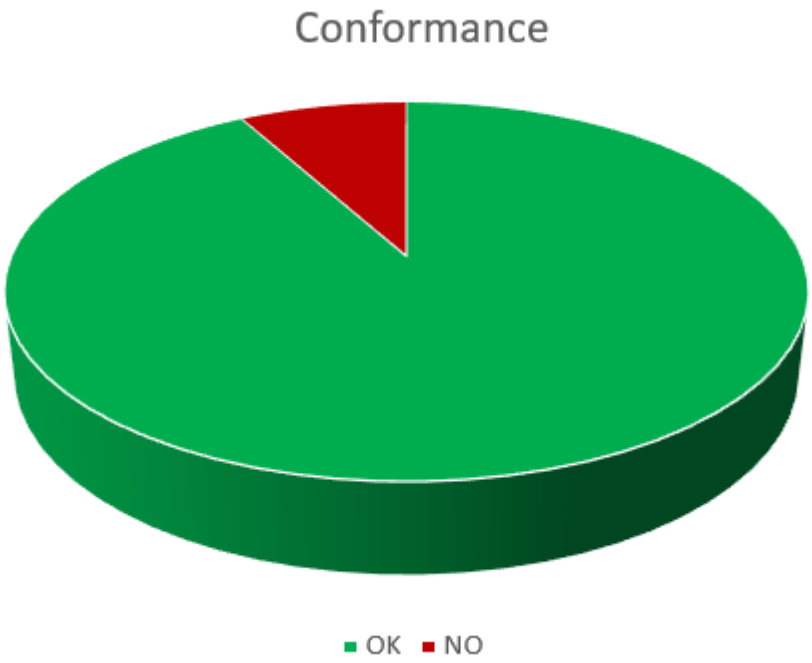


Figure 13. Overall results (%)

10 ETSI 5GAA Workshop on C-V2X Interoperability and Deployment

ETSI 5GAA joint Plugtests event workshop was organized on 4th Dec 2019 in Malaga on C-V2X Interoperability and Deployment which was attended by 65 people. Some of the prominent speakers were from European Commission Joint Research Centre which presented “JRC Activities on Cooperative Intelligent Transport Systems (C-ITS)” as well as Dutch Ministry of Infrastructure which presented “Dutch perspective on C-ITS deployment”.

The agenda of the workshop can be found here - https://5gaa.org/calendar/etsi-5gaa-plugtests-workshop/

11 Examples of Interoperability Testing in the Plugtests event

11.1 Road Works Warning Field Testing

The objective of this test is to verify the interoperability of ITS OBUs and RSUs in the context of Road Works Warning (RWW).

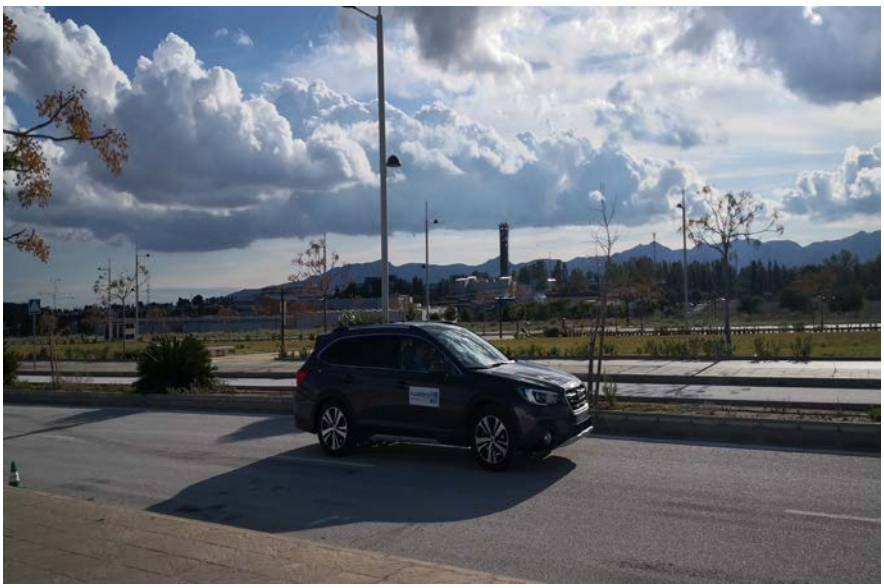


Figure 14. Road Works Warning Field Testing

11.2 Collision Risk Warning Field Testing

The objective of this test is to verify the Longitudinal Collision Risk Warning (LCRW) scenario. In particular it is determined whether an OBU is able to process CAM messages from other vehicle to determine a potential collision risk.

Figure 15. Collision Risk Warning Field Testing

11.3 Intersection Risk Warning Field Testing

The objective of this test is to verify the Intersection Collision Risk Warning (ICRW) scenario. In particular it is determined whether an OBU is able to process CAM messages from other vehicle to determine a potential collision risk.

Figure 16. Intersection Risk Warning Field Testing

11.4 LAB Based Testing

The lab testing consists of interoperability testing of ETSI Lab Based Interoperability Test Plan and 5GAA C-V2X lab-based Interoperability Test Plan.

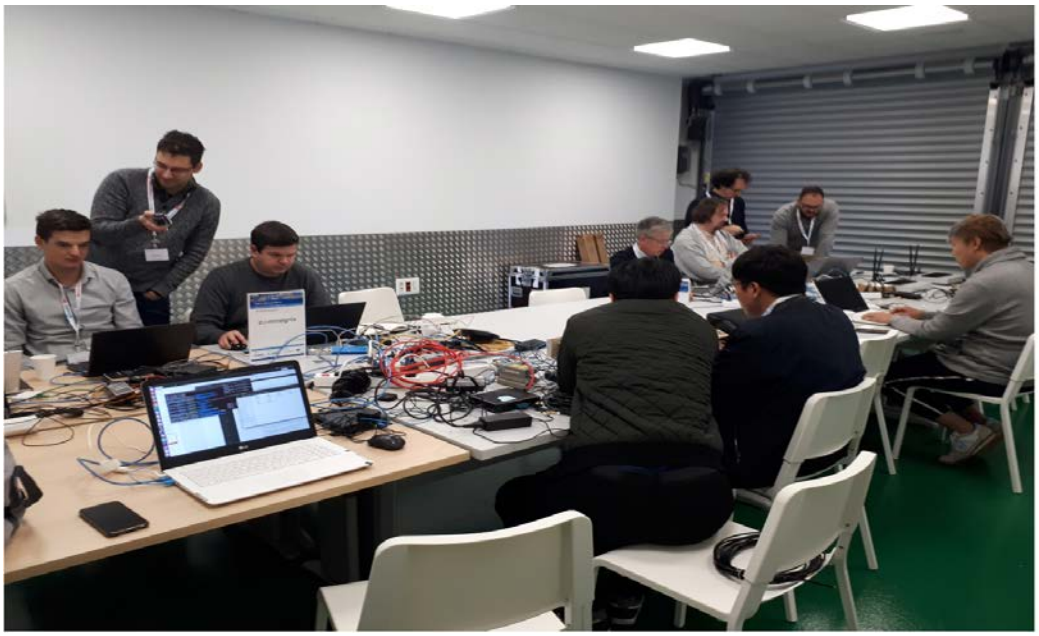


Figure 17. Lab Based Testing

History

Document history		
V0.1.0	09/12/2019	First Draft
V0.2.0	12/12/2019	Results from interoperability testing added
V0.3.0	17/12/2019	Results from conformance testing added
V0.4.0	18/12/2019	Minor corrections added
V1.0.0	19/12/2019	Final report