ETSI CTI Report V1.1.1 (2016-11)

TECHNICAL REPORT

5th ITS Cooperative Mobility Services Plugtest; Livorno, IT; 9 - 18 November 2016

Keywords

Testing, Interoperability, ITS

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
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Contents

Intellectual Property Rights

1 Executive Summary

ETSI, in partnership with ERTICO, has organized the latest in a series of Plugtests™ interoperability events for Intelligent Transport Systems (ITS) Cooperative Systems. This event was hosted by CNIT, from 9 to 18 November in Livorno, Italy. The support of the Livorno Port Authority, the Tuscan Regional Government, Autostrade, TIM and AVR (the FI-PI-LI highway operator) allowed to provide an execptional test infrastructure including a harbour test track, a highway test track and access to the FI-PI-LI traffic control center.

Participating companies from the automotive sector tested the interoperability of their solutions. In addition they ran tests to assess their compliance with ETSI ITS Release 1 developed by the ETSI ITS technical committee. The event also included M2M use cases, gathering experts from both public and private organizations specializing in ITS and IoT technologies and implementations.

At this Plugtest many C-ITS platforms demonstrated their interoperability by participating at state of the art safety use cases. The test results showed that the V2X technology is deployable in the near term and that it provides the necessary performance to meet use case requirements of today. Furthermore, the M2M and infrastructure use cases were successfully tested and as a result it can be stated that the V2X technology is capable of meeting requirements of use cases of tomorrow.

2 References

The following base specifications applied for the Plugtest.

[1] IEEE 802.11-2012: IEEE Standard for Information technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY).

[2] ETSI EN 302 636-4-1 (V1.2.1): "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 302 636-5-1 (V1.2.1): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 5: Transport Protocols; Sub-part 1: Basic Transport Protocol".

[4] ETSI EN 302 637-2 (V1.3.2): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[5] ETSI EN 302 637-3 (V1.2.2): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

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

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

[9] ETSI TS 102 894-2 (V1.2.2): " Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary"

[11] IETF RFC 7252: "The Constrained Application Protocol (CoAP)"

[12] IETF RFC 7641: "Observing Resources in the Constrained Application Protocol (CoAP)"

[13] IETF RFC 7400: "6LoWPAN-GHC: Generic Header Compression for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)"

[14] IETF RFC 7388: "Definition of Managed Objects for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)"

[16] IETF RFC 7428: "Transmission of IPv6 Packets over ITU-T G.9959 Networks"

3 Abbreviations

CAM	Cooperative Awareness Message
DENM	Decentralized Environmental Notification Message
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
ITS-S	ITS Station. Can be either RIS or VIS. This acronym is used when the role of the ITS Station is not relevant for the scope of the test. Note: When the role is relevant for the test, then RIS or VIS is used.
MAC	Media Access Control layer of the access layers
PHY	The Physical layer of the access layers
NO	Test is recorded as NOT successfully passed
NA	Test is not applicable
OK	Test is recorded as successfully passed
OT	Test is recorded as not being executed due to lack of time
Test Session	A paring of vendors that test together during a given time slot
TSR	Test Session Report. Report created during a test session

4 Host and Participants

4.1 Host

This event was hosted by T CNIT. The support of the Livorno Port Authority, the Tuscan Regional Government, Autostrade, TIM and AVR (the FI-PI-LI highway operator) allowed to provide an execptional test infrastructure including a harbour test track, a highway test track and access to the FI-PI-LI traffic control centerwho realized the test site layout, provided the test facilities and test support

4.2 Participants

The companies which attended the Plugtests are listed in the table below.

Table 1: List of teams

#	Teams
1	Aricent
2	Autostrade
3	Cohda /NXP
4	CNIT
5	Commsignia
6	Ctag
7	Delphi
8	Denso
9	Dynniq
10	Escrypt
11	Itri
12	Kapsch
13	Leghorn
14	Marben
15	Neavia
16	New Generation Sensors
17	Nordsys
18	Qfree
19	Renesas
20	Savari Networks
21	Siemens
22	Swarco
23	SystemX
24	Unex
25	Yogoko

The test tool vendors which attended the Plugtests are listed in the table below.

Table 2: List of test tool vendors and support companies

#	Vendor	Role
1	Cohda	ITS-G5 Modems for Conformance Test Setup
2	Commsignia	ITS-G5 Modems for Conformance Test Setup
3	Elvior	Conformance Test Runtime Environment
4	Spirent	Conformance Test Runtime Environment
5	DataCH	3D rendering of harbour and test track
6	AVR	FI-LI-PI highway operator

Table 3: List of represented projects

#	Project
1	ECo-AT
2	SCOOP@F

5 Technical and Project Management

5.1 Test Plan

The test plan containing 10 ITS use cases and 3 IoT use cases was developed by ETSI CTI together with a team of experts. The test plan is part of the present zipped container.

5.2 Test Scheduling

The preliminary test schedule was developed before the Plugtest and was circulated to all the participants in advance for comments. Each OBU vendor was provided with a test vehicle in which the OBU was installed. Each RSU vendor had an allocated location on the test tracks where their RSU was installed. The test schedule allowed for each OBU vendor to test against all RSUs. Each day was organized in a morning test session from 9.00 to 13.00 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.

Because of the high number of participating companies a 8 day schedule was organized (Wednesday 9 to Thursday 17 November). On Friday 18 November the RSUs were removed from the test track and all test vehicles were returned.

5.3 Test Infrastructure

5.3.1 Introduction

The Livorno Port Authority, AVR (managing the Livorno/Florence highway), and Autostrade Tech (managing motorway network) jointly provided the most significant part of the test infrastructure for the C-ITS Plugtest 2016 which consisted of the PLugtest Headquarter, the harbour test track as well as the high way test track.

5.3.2 Harbour test track

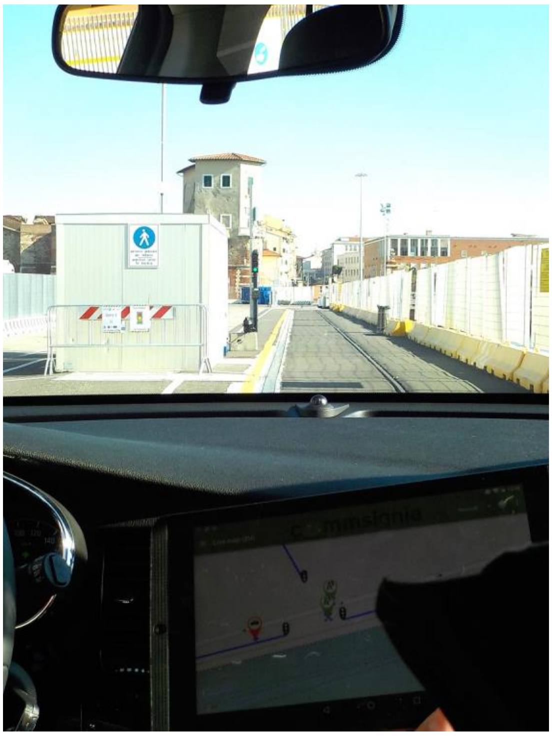
5.3.2.1 Point A

Picture 1: Point A – Commsignia Traffic Light

Picture 2: Point A – Commsignia RSU

Picture 3: Point A – Unex RSU

5.3.2.2 Point B



Picture 4: Point B – NXP Traffic Light (with Dynniq Traffic Light Controller)

Picture 5: Point B – Cnit, Dynniq and Yogoko RSUs

5.3.2.3 Point C

Picture 6: Point C – Neavia traffic light

Picture 7: Point C – Aricent, Neavia, Swarco and Siemens RSUs

5.3.2.4 Point D

Picture 8: Point D – Qfree traffic light

Picture 9: Point D – Ctag, Savari, Kapsch and Qfree RSUs

5.3.3 Highway test track

The highway test track consisted of a section of the Livorno/Florence highway as shown in the picture below

Picture 10: Highway Test Track

AVR provided access to a gantry in which the RSUs from CNIT, Siemens and Swarco were installed. The RSUs were connected with the Plugtest Test Network, i.e. interconnection of AVR control room, RSUs, Plugtests headquarter and remote labs in Stuttgart, Germany and Vienna, Austria. The picture below shows the RSUs from Siemens and Swarco.

Picture 11: Highway Test Track – Siemens and Swarco RSUs

For the UC1 – Road Works Warning the leftmost lane of the highway was closed. In the picture below the closed lane is shown, and the RSUs in the gantry are visible.

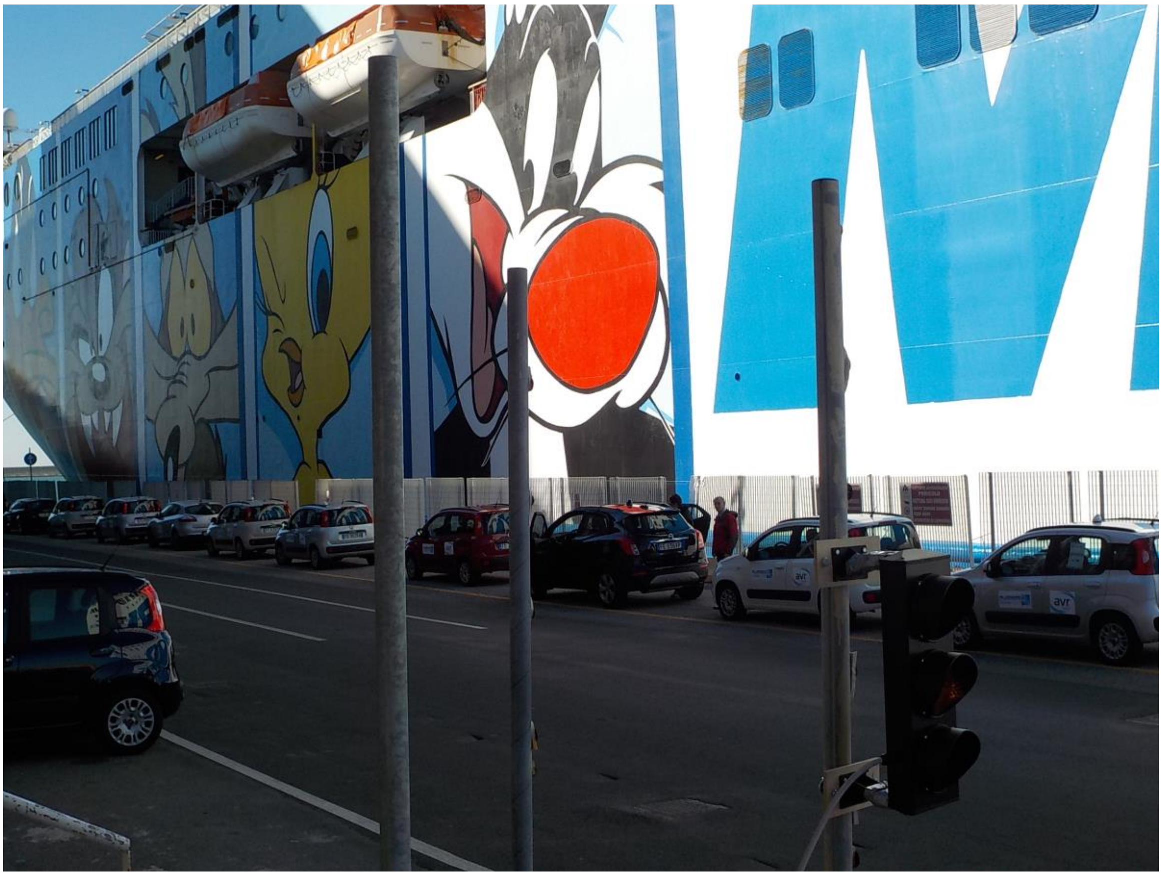
Picture 12: Highway Test Track – closed lane and RSUs in gantry

5.3.4 Plugtest Headquarter

The Port Authority provided the cruise terminal which was used as Plugtest headquarter. More than 80 tables were installed to seat the organizers as well as the participants. The Plugtest headquarter is shown in the picture below.

Picture 13: Plugtest Headquarter

AVR provided the test vehicles and dedicated drivers who where available during the schedule test sessions. Each ITS vendor had a dedicated car thus setting up the equipment only once. The picture below shows a part of the test vehicle fleet.



Picture 14: Fleet of test vehicles parked in front of the Plugtest headquarter

The ‘Port Innovation Workshop’ took place in parallel with the Plugtest. Workshop participants could explore the Plugtest exhibition corner and take a demo ride with the test vehicles. The Plugtest exhibition and the demo rides were organized at the Plugtest headquarter. The picture belwo shows the Plugtest exhibition corner.

Picture 15: Exhibition area

The picture below shows the workshop attendees waiting for their demo ride with one of the test vehicles.

Picture 16: Queue for demo rides

5.3.5 GPSD Server

The GPSD server emulated the movement of cars of the Zone 1 of 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

The source code for the GPSD server is available at https://forge.etsi.org/svn/_ITS_GPSD_SERVER/branches/

5.3.6 PKI Setup

For the Plugtest two PKIs were provided. One PKI from Escrypt. The other PKI from SystemX. The PKIs enabled to retrieve ITS certificates as defined by ETSI TS 103 097 v1.2.5. The communication with the PKI provided by Escrypt was done using HTTP over TCP over IP (IPv4) using a SOAP web service secured with TLS. The communication with the PKI provided by SystemX was done using HTTP over TCP over IP (IPv4) secured with ETSI TS 102 941 v1.1.9.

This setup allowed to test a real deployement scenario were a vehicle needs to trust more than one PKI provider.

5.3.7 DATEXII Integration

One of the objectives of the Plugtest was to demonstrate conformance and interoperability of the communication on the G5 radio, under real life conditions, with the end-2-end equipment chain from Traffic Control Center to Applications in the test vehicles.

Autostrade provided with the access to their DATEXII node an important element of this equipment chain. The system architecture of the DATEXII integration is shown in the figure below.

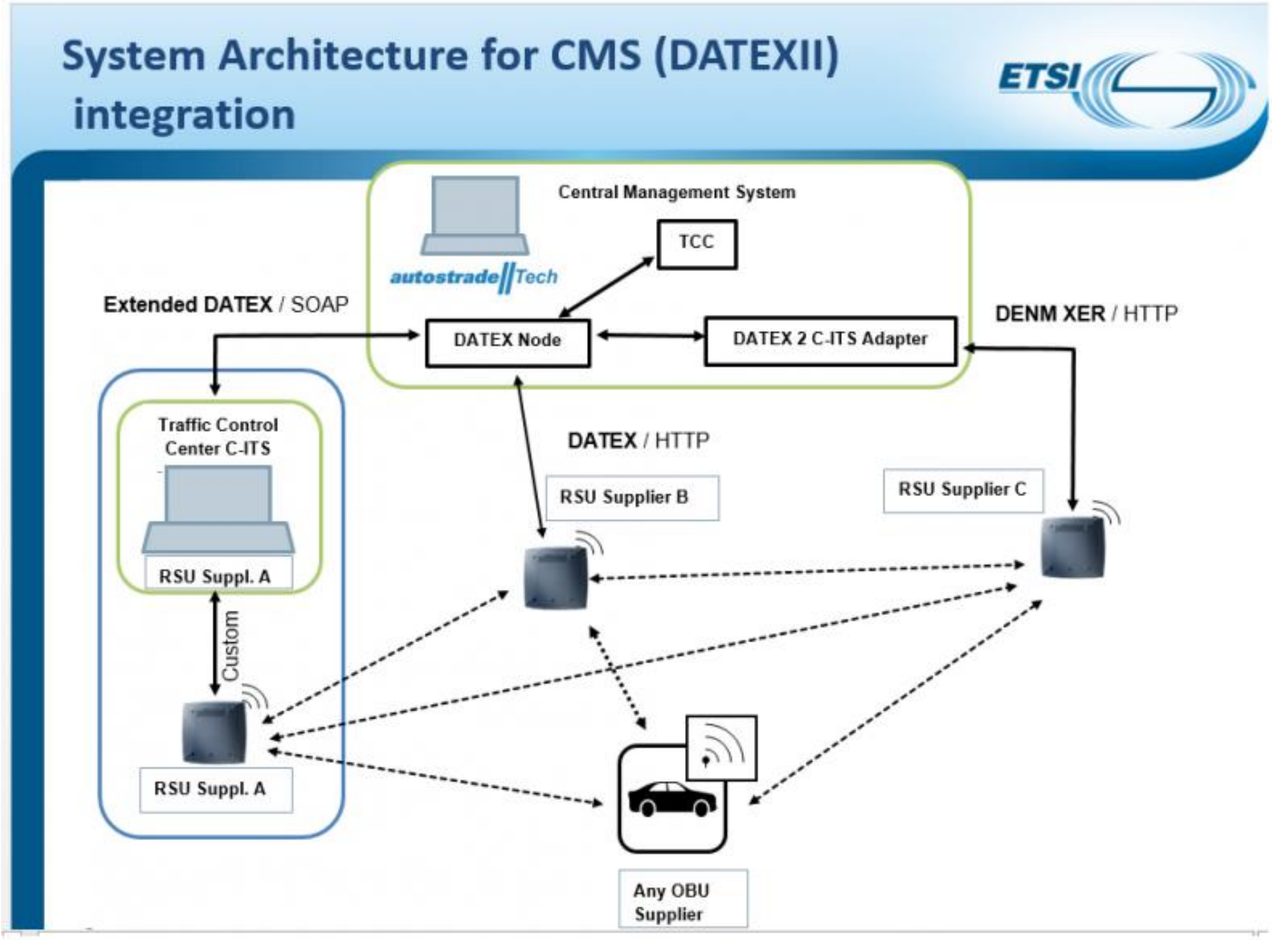


Figure 1: DATEXII Integration

To widen the participation of vendors to this integration and to support the implementations coming from earlier European projects, three different communication interfaces were provided:

- Basic DATEX http/get interface
- Basic DATEX WSDL push/pull interface
- DATEX content by OCIT-C interface

In addition a conversion from DATEX format to XER DENM had been implemented by Autostrade from their DATEX System (DATEX 2 C-ITS Adaptor in the figure above) acting as a C-ITS-S delivering messages to R ITS-S. A detailed interface to provide XER DENM messages to R ITS S was developed.

The architecture set up supported vendors that implemented CITS-Ss to interact with the Traffic Control Centers as well as vendors that implemented RSUs to interact with the Traffic Control Center. The data flow contained real events from the test site (i.e. road events about FiPiLi and Motorway) and simulated events.

5.3.8 Conformance Validation Framework

The ETSI ITS Conformance Validation Framework is a test software to assess the base standard compliance of a vendor implementation, as shown in the figure below. The Conformance Validation Framework was used for the pre-testing activity, see clause 6.2 .

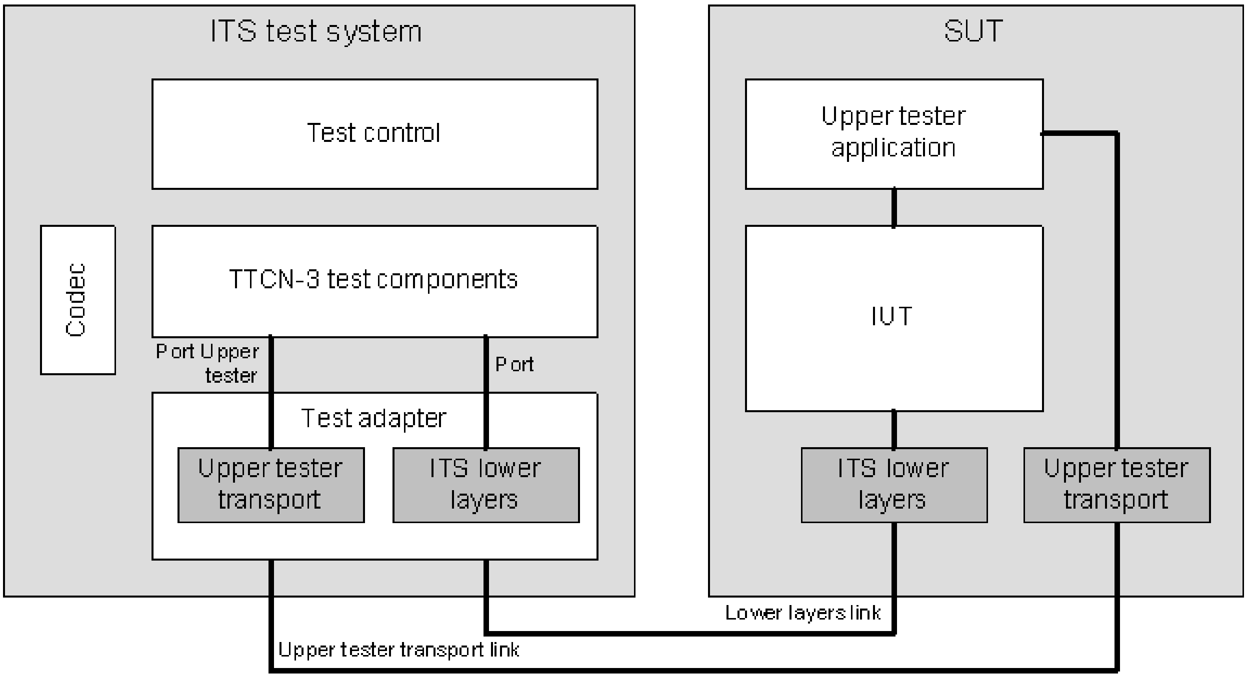


Figure 2: Conformance Validation Framework

5.4 Blog

The Plugtest blog is accessible at http://www.etsi.org/news-events/events/1054-plugtests-2016-itscms5?tab=4.

6 Achieved Interoperability Results

6.1 Overview

The Plugtest was organized in the following phase

1. Phase 1: Test Track Design
    a. Livorno-Florence highway
    b. IoT testbed
    c. Test track through the port of Livorno
2. Phase 2: Pre-qualification of Device Under Test (DUT)
    a. Conformance Testing
3. Phase 3: Connecting all participants
    a. Remote labs
    b. Autostrade DATEXII Node integration
    c. RSUs in harbour and highway test track
4. Phase 4: Testing !
    a. 1 week lab test in Cruise Terminal

b. 1 week of field tests on test track

The following clauses cover all phases.

6.2 Test Track Design

In a first step a principal route of 2,5 km in the harbour and 10 km on Fi-Pi-Li highway was identified. On this principal route there were 11 potential RSU locations where electricity and internet connection could be provided. Radio coverage measurements were conducted to select the locations which allowed the largest radio coverage. Finally four RSU locations were retained.

In a next step the test track was devided into six zones; and each RSU was allocate a dedicated zone. The figure below shows the RSU locations A,B,C,D and the zones (highlighted in grey).

Picture 17: RSU locations and zones

The table below shows the RSU allocation.

RSU location	RSU dest area	Vendor
A	Zone1	Unex
		Commsignia
B	Zone2	Cnit
		Dynniq
		Yogoko
C	Zone3	Neavia
		Swarco
	Zone6	Aricent
		Siemens
D	Zone4	Ctag
		Savari
	Zone5	Kapsch
		Qfree

Table 4: RSU allocation

Then a GPS recording of the vehicle path was created. Based on this GPS recording the zone-specific messages were designed, i.e. the DENM traces, MAP stop lines, reference points etc were chosen in reference to the GPS recording.

6.3 Pre-testing

Before attending the Plugtest the participants were offered the possibility to validate their compliance to the ETSI Release 1. This step in the Plugtest preparation was important, as it helped to detect and mitigate potential errors early on, rather than having to debug these issues in the field on the test track.

Table 5: List of available test specifications

Base Standard	ETSI Test Specifiction
ETSI EN 302 637-2 v1.3.2: CAM base specification	ETSI TS 102 868-1,2,3 (V1.4.1 available in Feb 2017)
ETSI EN 302 637-3 v1.2.2: DENM base specification	ETSI TS 102 869-1,2,3 (V1.5.1 available in Feb 2017)
ETSI EN 302 636-4-1 v1.2.1: GN base specification	ETSI TS 102 871-1,2,3 (V1.4.1 available in Feb 2017)
ETSI TS 103 097 V1.2.1: Security header and certificate formats	ETSI TS 103 096-1,2,3 (V1.3.1 available in Feb 2017)
ETSI TS 103 301 V1.1.1: Infrastructure Services	ETSI TS 103 191-1,2,3 (V1.2.1 available in Feb 2017)
Note : The test scripts are developed in TTCN-3 (for more information on TTCN-3 see www.ttcn-3.org)	

The tests are available at the following location (login: snvusers, pwd: svnusers).

ASN.1 files

https://forge.etsi.org/svn/ITS/branches/STF517/asn1/

ATS

https://forge.etsi.org/svn/LibIts/branches/STF517/ttcn

LibIts

https://forge.etsi.org/svn/LibIts/branches/STF517/ttcn

LibCommon

https://forge.etsi.org/svn/LibCommon/tags/v1.4.0/ttcn

Codec/TA

https://forge.etsi.org/svn/ITS/branches/STF517/javasrc

To support the debugging of detected compliance problems ETSI developed a dissector for Wireshark. Thsiis available at https://forge.etsi.org/svn/WIRESHARK_ITS_PLUGINS/releases.

Note: It is planned to release the ITS test specifications via TC ITS in early 2017. The release will include bug fixes of issues found during the PLugtest, but will not differ in any other way. This upcoming release can hence be used as reference for future projects..

6.4 Connecting All Participants

The remote test infrastructure was based on the connection of all the Equipment Under Test from all the participating companies to the Hub for Interoperability and Validation at ETSI (HIVE) via IPSec GRE VPN Tunnels.

In this setup, ETSI acted as a VPN HUB and enabled the interaction among any possible equipment combination over a secure transport network.

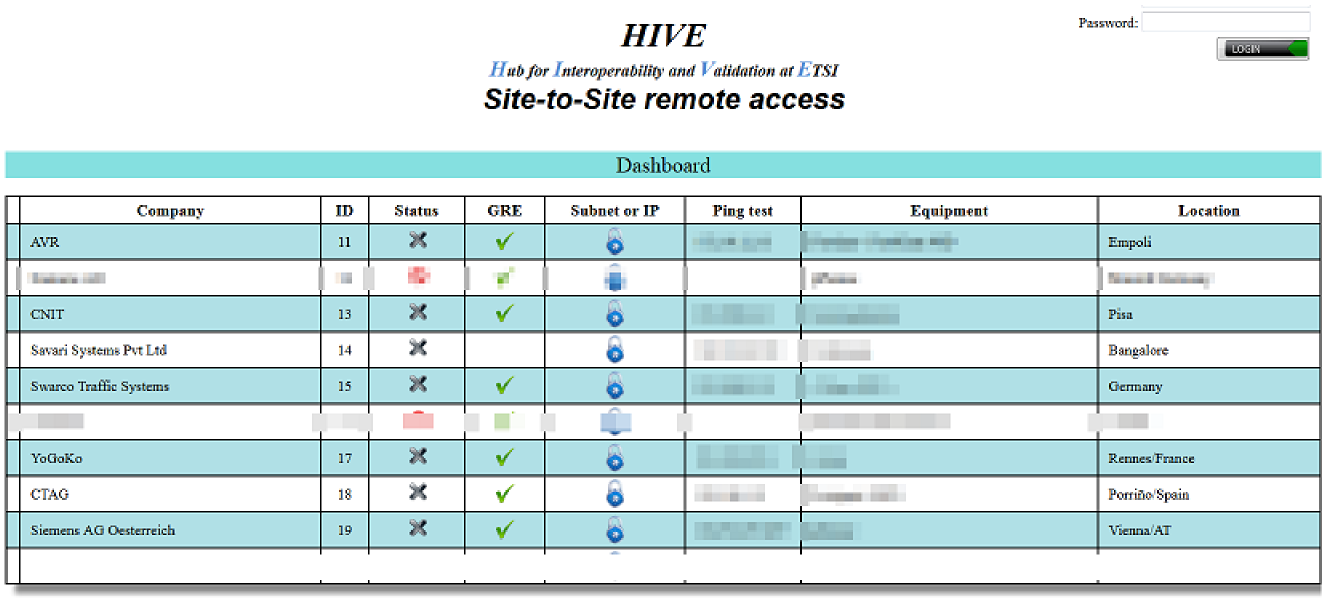
Consequently, connecting the equipment under test to HIVE was a mandatory step to being able to participating to the remote pre-testing phase of the Plugtest.

In order to facilitate the integration of remote companies the following initiatives were put in place:

1) A VPN Request application accessible from the WIKI allowing participants to fill-in all their technical details and to automatically trigger the VPN configuration and setup.

2) A pre-configured VPN Router loan service. ETSI put in place this fast-track process with the objective to accelerate the integration of Plugtest participants. Participants that wished to benefit from this possibility could request it on the VPN request application, and received within a few days a pre-configured VPN router allowing them to connect their equipment under test to HIVE within a few minutes.

The VPN request application also allowed participants and organisers to monitor the status of the VPN creations.



Company	ID	Status	GRE	Subnet or IP	Ping test	Equipment	Location
AVR	11						Empoli
CNIT	13						Pisa
Savari Systems Pvt Ltd	14						Bangalore
Swarco Traffic Systems	15						Germany
YoGoKo	17						Rennes/France
CTAG	18						Porriño/Spain
Siemens AG Oesterreich	19						Vienna/AT

Figure 3. VPN Request application

A flexible network architecture was designed to enable inter-connection of Central ITS-S located at remote labs, RSU on the harbour test track, RSU on the highway test track and monitoring and control equipment at the Plugtest headquarter.

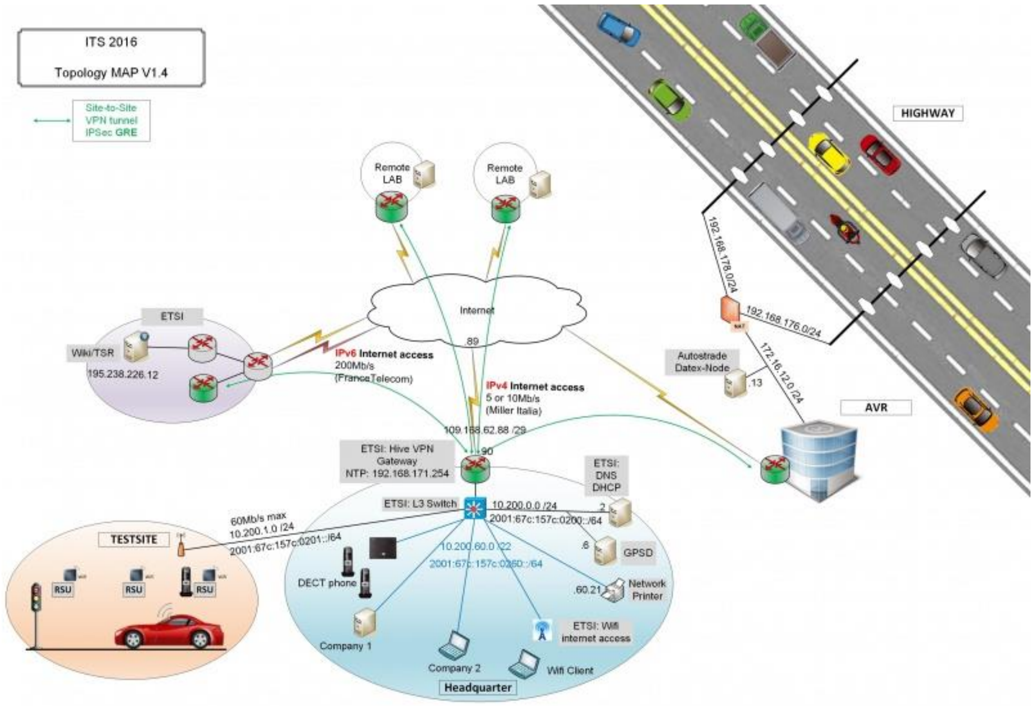


Figure 4. Network Architecture

6.5 Lab Mega Session

During the first week of the Plugtest the OBUs and HMIs were validated by sending from the ETSI RSU simulator pre-defined messages according to the Use Case constraints. RSU vendors had as well the opportunity to send the pre-defined messages thus validating their RSU-behaviour.This was the last check before going on the test track. The lab mega session took place at the Plugtest headquarter. The code of the RSU simulator is available at https://forge.etsi.org/svn/ITS/branches/STF517/ttcn/AtsRSUsSimulator .

The GPSD server provided the location information for the OBUs. It emulated the movement of cars of the Zone 1 of 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. The source code for the GPSD server is available at https://forge.etsi.org/svn/_ITS_GPSD_SERVER/branches/

6.6 IoT Use Cases

6.6.1 Introduction

The Plugtest tested in real-life conditions innovative IoT-ITS scenarios: an event detected at the IoT gateway is notified to the surrounding vehicles through the ITS stack. The events tested covered environmental sensing (hazard or pedestrian on the road, loading / unloading zone management) and on board sensing (vehicle with dangerous goods on the road).

6.6.2 Testplan and use cases

Three use cases were planned for the joint IoT-ITS tests. These tests involved smart objects connected to an M2M gateway located either in an OBU (UC2) or an RSU (UC1 and UC8). When triggered by the reported value received from the smart object, the ITS station would disseminate an ITS message to notify the surrounding ITS stations. The protocol stack illustrated in figure 5 was adopted for the tests.

Applications	
ITS Facilities	CoAP
BTP / GN	UDP / 6LowPAN
ITS-G5	IEEE 802.15.4

Figure 5: IoT-ITS protocol stack

UC1: Hazard on the road

The objective of this test is to notify ITS stations that a danger on the road (pedestrian, fuel, …) has been detected by an IoT-enabled smart object. The RSU polls the IoT device, and if a condition is met, it broadcasts a corresponding DEN Message to the surrounding vehicles indicating the hazard position.

UC2: Dangerous goods vehicle

The objective of this test is to notify ITS stations that a vehicle carrying dangerous goods is driving or stopped on the road. An IoT-enabled smart object is installed in the vehicle. The OBU of the vehicle polls the device and transmits a CA Message indicating "dangerous goods vehicle" information to the surrounding vehicles. If the vehicle stops on the road, it transmits a warning in a corresponding DEN Message.

UC8: Loading / Unloading Zone management

The objective of this test is to notify ITS stations that a loading / unloading parking space is available in the harbour. The RSU polls an IoT device, and if a parking place is detected as free, it broadcasts a corresponding PoI Message to the surrounding vehicles indicating the loading/ unloading zone position. The PoI message used for this test was a deviation of the EVCSN (Electric Vehicle Charging Spot Notification) message specified in ETSI TS 101 556-1.

6.6.3 Participants

The participants to the IoT-ITS tests were divided in the following categories.

- Smart object providers: three participating companies provided their sensors, based on Infra-red, magnetic detection or RFID security seal: Aricent, LeghornGroup and NGS.

- IoT gateway - ITS stations: two participating companies provided ITS stations able to communicate with the sensors: CNIT and Aricent. Both companies were able to provide an OBU for UC2 as well as an RSU for UC1 and UC8.

- Receiving ITS stations were standard OBUs for UC1 and UC2. UC8 necessitated the support of the PoI message by the OBU, which was provided by three companies: CNIT, Aricent and CTAG.

6.6.4 Test preparation

A test plan covering all three use cases was developed and maintained during the preparation time (clause 6 "IoT Test Scenarios" of the CMS5 Plugtests Guide).

The IoT specific use cases were discussed during the regular CMS5 phone calls, and during two additional dedicated calls held on 08/09/2016 and 20/10/2016. Clarifications were already discussed during these calls, such as:

- confirmation of detection method: no pre-defined DENM, the initial detection takes place at the start of each session and is valid for the whole session duration (e.g., no real human to trigger the pedestrian on the road hazard, but rather use the manual trigger of a real sensor),

- list of devices available for the tests and their capabilities,

- protocol stack to be used (see Figure 5), the communication between the sensor and the gateway is IEEE 802.15.4 (short range),

- communication between the IoT device and the gateway, based on polling rather than pushing (CoAP periodic GET method rather than OBSERVE, which however would be less power consuming in real life),

- integration of the gateway with the ITS station by each vendor (interoperability at IoT level is not in the objectives),

- access layer channel used for UC8 is the ITS G5-CCH with the channel number 180, even if in real life it should be a service channel,

- periodicity of the ITS messages to be sent,

- insertion of the DENM cause codes to be used in the wiki for each use case.

6.6.5 Illustration of tests

The IoT tests were integrated in the main Plugtests schedule and run mainly from zone 2 (CNIT RSU located in point B) and zone 6 (position of Aricent RSU in point C). The pictures below illustrate these tests.

Figure 6: RSU from CNIT with NGS sensor

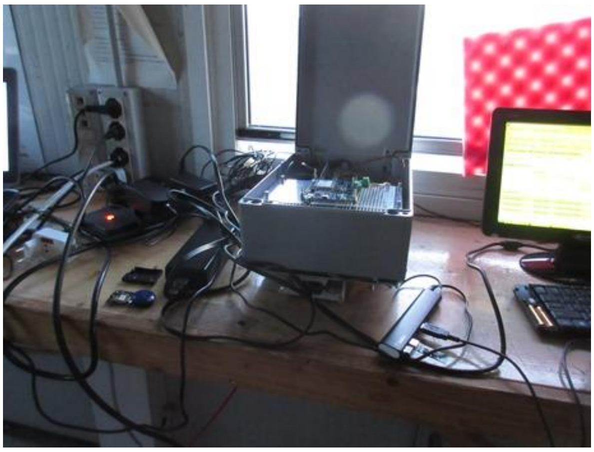


Figure 7: RSU from Aricent

Figure 8: Vehicle carrying dangerous goods

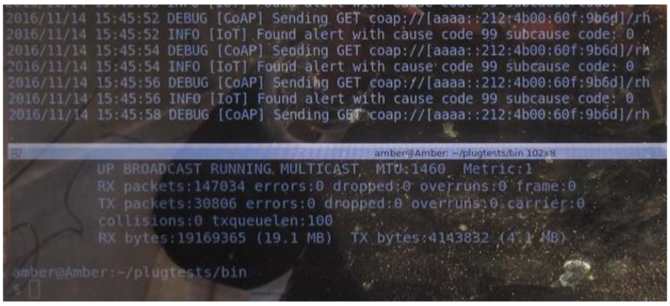


Figure 9: Screen capture logging IoT and ITS DENM messages for UC1

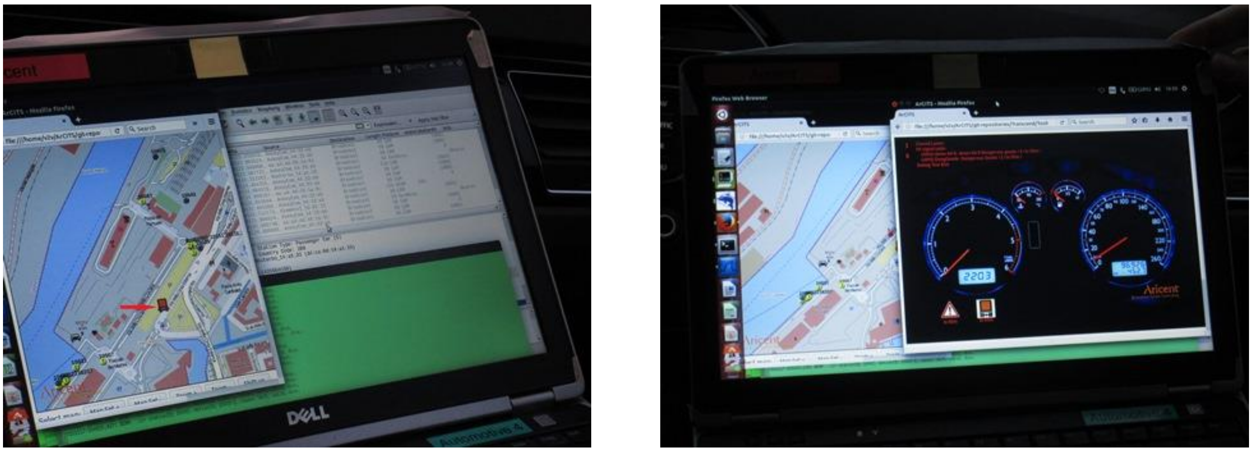


Figure 10: Display showing result of UC2

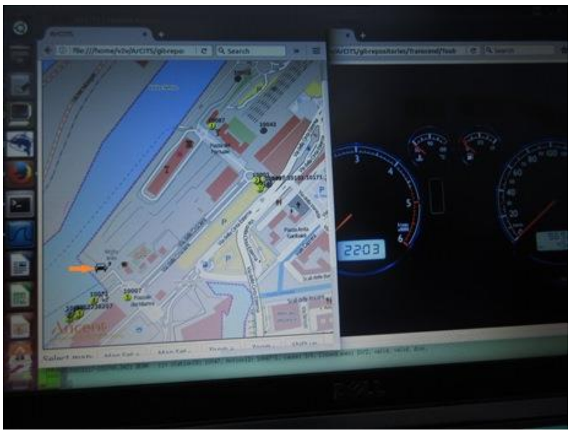


Figure 11: Display showing result of UC8

6.6.6 Dissemination

This IoT-ITS Plugtests campaign was presented at the ETSI IoT / M2M workshop, on November 17, in ETSI Headquarters. A copy of the final presentation is available at:

https://docbox.etsi.org/Workshop/2016/201611_M2MIoTWS/00_WORKSHOP/S08_IoTinVERTICALS/CNIT_Petracca.pdf

6.7 ITS Use Cases

Per round on the test track up to four tests could be executed. More than 370 test result were reported with a toal of 80% interoperability as shown in the table below.

Table 6: Overall result

Interoperability		
OK	**NO**	**Run**
300 (80.0%)	75 (20.0%)	375

A highlight of the Plugtest was the fact that many well advanced applications were deployed. UC3 - Time To Green and UC6 - Intersection Collision Risk Warning were ideal for the demonstration of the applications.

In the following clauses each use case is shortly discussed. The discovered interoperability issues are described in clause 6.8 .

6.7.1 UC1 - Road Hazard Signalling

14 RSUs and 15 OBUs performed this use case on the harbour test track as well as on the highway test track. The change request on DrivingLaneStatus was successfully validated, see also clause 7.4 and Annex A.

6.7.2 UC3 - Time To Green / Traffic Sign Violation

12 RSUs and 13 OBUs performed this use case. Many vendors agreed that the current SPAT Timemark is not the most efficient way to indicate timing.

6.7.3 UC4 - Vehicle Data Aggregation

7 RSU vendors performed this use case. Each RSU individually captured the traffic.

6.7.4 UC5 - In-Vehicle Signage

10 RSUs and 9 OBUs performed this use case. This was a straight forward test, however it was agreed that the IVI ASN.1 typing is too complex and hence can easily cause interoperability issues.

6.7.5 UC6 - Intersection Collision Risk Warning

8 OBUs performed this use case. This use case was validated successfully and each vendor had a well working application.

6.7.6 UC7 - Longitudinal Collision Risk Warning

6 OBUs performed this use case.

6.7.7 UC9 - Tolling

7 RSU vendors and 9 OBUs performed this use case on the harbour test track as well as on the highway test track. Each OBU vendor could decode the ProtectedCommunicationZonesRSU CAM message sent by the RSUs and apply the TX power reduction mitigation method.

6.7.8 Security

6.7.8.1 Secured Communication

14 vendors did run the use cases UC1, UC3 and UC5 in secured mode successfully, both in the mega session as well as on the test track.

A highlight of the secured mode test session was that simultaneous usage of two PKIs was successfully tested. One vendor used certificates provided by Escrypt PKI and 3 other vendors used certificates provided by SystemX PKI. These vendors could communicate together in secured mode on the test track.

6.7.8.2 Certificate Reloading (UC10)

10 vendors were able to obtain certificates in the lab using an IPv4 connection to the PKIs.

2 vendors were able to obtain certificates on the track using IPv6 over G5.

6.8 Interop Issues

6.8.1 IoT

- Interpretation of the IoT device signal. The main issue was whether subsequent active detections (e.g. for pedestrian) should be considered as new events or the same event. The initial settings tested considered them as different events, thus triggering a new DENM with a different sequence number at each period, i.e. every second. The OBUs receiving the messages were then rapidly flooded by this large set of DENMs. In a first step, it was agreed to send the messages with a longer period of 5 seconds, and set the message validity duration to 4.5 s. In real life the tests would rather use the AppDENM_update application request, as specified in the DEN basic service standard, ETSI EN 302 637-3. This issue has demonstrated the necessity to clearly define (maybe with specific new standards) the interpretation of sensor data and how they trigger actions from the applications.

- Some issues were encountered in the construction of the DENM messages by the testing IoT-ITS stations, mainly for indicating the position of the event, the relevance distance (without location container, as it was not required here) and the value of the repetition interval. Most of them were fixed during the event to enable the validation of the results.

6.8.2 GPS

The zone 1 of the Harbour test track, see picture below, was a challenge for the GPS signals. The presence of the high boat on the left facing the high building on the right created an environment typical of an urban canyon. This well-known issue of GPS geo-positioning in this type of environment results from the partial blocking of satellite signal reception (in the GPS system, the higher the number of different satellite signals received, the better the accuracy of the positioning is) as well as the multipath reflections on the building and even more, on the metallic side of the boat. The result is a lack of accuracy of the GPS positioning, as was experienced by some of the OBU receivers during the test. When monitoring vehicle traces through the received CAM messages, the apparent vehicle position has been often 10-20 meters off the road. Such positioning inaccuracies cause problems for use cases which rely on the position/heading of the vehicle, such as red light violation warning or intersection collision warning. It demonstrates that GPS positioning is not sufficient for traffic safety applications, and that fusion algorithms with complementary positioning systems are required. During the wrap-up sessions the participants were informed of two projects which address this topic:

- Ongoing project: the HIGHTS project (http://hights.eu/)

- Completed project: A high-precision cooperative RTK GNSS positioning solution has been tested in the AutoNet2030 project (www.autonet2030.eu). All metrics were collected in two different modes; cellular (correction data coming from the SWEPOS network using a cellular modem), and ITS-G5 (correction data coming from a base station SW calculation, broadcast over multi hop ITS-G5 short range communications). For the position accuracy in the ITS-G5 case, the accuracy is dependent on the precise location of the base station, which can be self-calibrated using long-term measurement averaging.
  Lock time of the module is fairly long since it is using a single frequency receiver. Even though lock time was in the order of minutes, it was discovered to be fairly constant. No difference could be seen between cellular and ITS-G5 modes.
  Position accuracy was measured against a Trimble system with proven high accuracy. The promised few cm level accuracy compared to the Trimble ground truth was reached in all tests. Smoothness of the output was also investigated and deemed to be correct, both in low-speed and high-speed dynamic driving scenarios. The following figure illustrates the accuracy of the obtained position accuracy on a two-lane test track. It shows the tracking of the vehicle in front from the perspective of the ego-vehicle in the middle; left side shows the radar tracking view, while the brown line in the right side shows the GNSS trace of the vehicle which has been communicated through the CAM message broadcasts. As can be seen from the figure, the obtained positioning data can always unambiguously indicate the driven lane of the vehicle during this highway scenario test.

Figure 12: Urban canyon of test track

6.8.3 Backwards compatibility

6.8.3.1 MAP/SPAT versioning

There had been some discussions about the backward compatibility issue that arose with the MAP/SPAT ASN.1 definitions for the Plugtest.

The Plugtest 2015 used a version of SPAT/MAP messages which is different to the version used in the Plugtest 2016. Therefore TS 103 301 v1.1.1 should state : "For the present document, the value of the DE protocolVersion for SPAT, MAP etc shall be set to 2." However it was decided not to insist on the change to TC ITS WG1 due to the fact that a) the vendor parameter profiles were already frozen at the time of this discussion and b) the approval of TS 103 301 v1.1.1 had just finished.

6.8.3.2 Version Handling

- At the moment CDD TS 102 894-2 v1.2.1 is published;

- In case a non-backwards compatible CDD is released, and the facility layer standards weant to use this new CDD version, then they must be updated as well. For example of CAM the following steps would need to be undertaken:
  - raise the protocolVersion number in CAM EN 302 637-2 (the CDD.protocolVersion is used to indicate the version of a facility layer message, e.g. CAM, DENM, SPAT, MAP, IVI, …)
  - update the normative reference section of CAM EN 302 637-2 and point to CDD v1.3.1
- As a consequence the value ‘currentVersion(1)’ should be deleted from CDD.protocolVersion. This would remove the ambiguity whether this value 1 applies to CDD or the facility layer messages.
- CDD versions shall be managed via the document version , i.e. V1.2.1, V1.3.1 … .

6.8.4 Traffic Control Center

A total of four vendors integrated with the Autostrade DATEXII node as shown in the table below. A highlight was that one of the vendors installed its RSU in a gantry of the highway test track.

Table 7: Autostrade connections

	Autostrade Connection			
	RSU location	**Message Content**	**Device Type**	**Feed**
Vendor1	RSU on highway	Real Motorway roadworks	Central ITS-S	OCIT-C
Vendor2	RSU on test track	Simulated Harbour roadworks (3 lanes)	RSU	REST DENM XER
Vendor3	RSU on test track	Simulated Harbour roadworks (3 lanes)	RSU	REST DENM XER
Vendor4	RSU on test track	Simulated Harbour roadworks (3 lanes)	RSU	REST DENM XER

Most of the issues faced during the integration between ITS-Ss and the Traffic Control Center were caused by a lack of extensive pre-testing activity and discussion over the provided documentation. The main issues faced included:

1. Connectivity issues among remote sites;
   - The pre-testing phase was not long enough to debug all connectivity issues.
2. Non-conformant DATEXII implementations
   - validityStatus Management:
     the standard validityStatus provides the following options (definition available on DATEX reference document): active, definedByValidityTimespecs, suspended. In addition the status ‘closed’ was required by some vendors, and the status ‘suspended’ was used to indicate ‘closed’. The correct implementation would have been to extend the ValidityStatus with a “closed” situation record.
   - situation ID
     No semantic should be superimposed on it, i.e. treating situation ID to be the same as actionID in DENM Messages can lead to problems on the DATEXII side.
3. DATEX II content to DENM mapping
   The DATEX II content was filtered geographically and by content to suit the Plugtets use cases. PublicationDifficulties to set up simulated events in the DATEXII flow were encountered, which led to messages non conformant with interoperability test specifications;
4. DENM XER flow: most of the issues have been dealt with on site and a successful integration of UC1 was achieved. The only issue reported consisted of a not correctly formatted trace for the event. Still the notification was provided to the HMI by means of the Relevance Area data frame present in the message.

6.8.5 Security

The two PKI providers had implemented the certificate distribution differently. At the Plugtets most of the vendors had implemented the standardized certificate distribution, i.e. ETSI TS 102 941. The C2C PKI protocol is not compatible with the ETSI standard and hence it is recommended to converge the various PKI implementations towards the new release of TS 102 941. The following feedback was recorded.

6.8.6 DENM

The following interoperability issues were discovered:

- validityDuration in the past,
- WGS 84 altitude is around 50m, but OBUs reported 0m (altitude not available is 800001
- detectionTime and referenceTime are wrong
- Epoch time in ms used instead of TAI time

6.8.7 GN

The following interoperability issues were discovered:

- Hopping activated

6.8.8 POTI

As at every Plugtest there are many issues with time synchronization, time format and GPS accuracy. It is therefore recommended to conduct thorough POTI tests.

7 Base Specification Validation

All issues identified and listed in the present clause are minor issues and did not hamper the use case executions.

7.1 ETSI TS 103 301 v1.1.1

The table below lists the discovered base spec issues of ETSI TS 103 301 v1.1.1.

Table 8: Discovered IS base spec issues

#	Issue	Comment
1	All modules - named integers in the OID need to be unique throughout ASN.1 modules - Issue 7581	**Issue fixed and applied during Plugtest**
2	All modules - wrong OID in all modules - Issue 7582	**Issue fixed and applied during Plugtest**
3	IVI - type names should not be called ‘optional’ ‘mandatory’ - Issue 7579	
4	IVI - Type and field names not descriptive enough - Issue 7578	
5	IVI - Avoid inline definitions - Issue 7575	
6	IVI - logical problems with TractorCharacteristics and TrainCharacteristics types - Issue 7577	
7	IVI - how to handle future extensions - Issue 7576	
8	IVI - 'TcPart / data' and 'Text / textContent' fields: OCTET STRING or UTF8String with a length limitation - Issue 7574	
9	MAP - avoid length-specific ASN.1 typing - Issue 7580	
10	IVIM.ivi.optional.gic SSP - Issue 7587	
11	AdvisorySpeed SSP - Issue 7586	
12	SPATEM.spat.intersections. IntersectionState.status is mandatory and hence cannot be SSPed - Issue 7585	
13	SPATEM.spat.intersections. IntersectionState shoudl not be included in SSP - Issue 7584	

14	protocolVersion should be set to 2 - Issue 7583	

7.2 ETSI TS 103 097 v1.2.5

Based on various feedback such as the 4th ITS Plugtest, TC ITS WG5 had started end of 2015 to develp a bug fixed version based on v1.2.1. Six month prior to the 5th Plugtest version v1.2.5 was produced with the goal to validate this snapshot. Version v1.2.5 was successfully validated in the Plugtest and the table below lists the discovered base spec issues and potential fetaures of ETSI TS 103 097 V1.2.5.

Table 9: Discovered base spec issues and potential new features

1	Request of unrecognized AA certificate create high channel load when all receivers reply with a certificate chain – Issue6969
2	ITS-S should stop requesting an unrecognized AA certificate if the issuer of the AA certificate is untrusted – Issue6973
3	to add SSPs in the AA certificate – Issue 7559
4	SSP needs to be redesigned – Issue 7588

7.3 ETSI EN 302 637-3 V1.2.2

The table below lists the discovered base spec issues of ETSI EN 302 637-3 V1.2.2.

Table 10: Discovered DEN base spec issues

1	Negation of DENM is not protected by SSP - Issue - 7532
2	Improvement of the reference to related DEN messages for a specific traffic situation within a DEN message - Issue 7498
3	pseudonym change for active DENMs – Issue6980 (item from 2015 Plugtest)
4	StationID collisions - Issue6981 (item from 2015 Plugtest)

7.4 ETSI TS 102 894-2-1 V1.2.1

The table below lists the discovered base spec issues of ETSI TS 102 894-2-1 V1.2.1 .

Table 11: Discovered CDD base spec issues

#	Issue	Comment
1	extend value for SPAT/MAP/IVI/SSM/SRM - Issue 7209	**Issue fixed and applied during Plugtest**
2	[DE_DrinvingLaneStatus]: make it unnamed list - Issue 7296	**Issue fixed and applied during Plugtest**
3	Delete assigned version number ItsPduHeader.protocolVersion - Issue 7429	

The item of table 13.2 was implemented by all vendors and validated successfully. For all details to this item refer to the annex A of the present document.

7.4 ETSI TS 101 556-1 V1.1.1

The table below lists the discovered base spec issues of ETSI TS 101 556-1 V1.1.1 .

Table 12: Discovered EVCSN base spec issues

#	Issue	Comment
1	Timestamp is not exported from ItsContainer - Issue - 7440	**Issue fixed and applied during Plugtest**
2	OID of CDD is wrong – Issue 7061	**Issue fixed and applied during Plugtest**

8 Results of Plugtest Survey

8.1 Review of feedback from Plugtest#4

- Even though the first four days of the Plugtest#4 were focused on conformance testing, it was noted that still more conformance testing prior to a next Plugtest is needed. A gating criteria to enter the Plugtest could be to pass the conformance tests. This would allow to understand which features and to what level features are supported; and consequently more effective scheduling could be done.
    - A pre-testing was performed at Plugtest#5.
- The success of the Plugtest#4 Live Demo opened the floor for discussion on the topic whether the scope of next Plugtests should include field trials, as the majority of ITS vendors has passed all indoor lab tests, and would be ready for more advanced and real-world test scenarios.
    - The scope was shifted to field trials at Plugtest#5.
- No Security Profile 3 tests were executed due to the open base spec issue on ITS-AID
    - Test were available at Plugtest#5.
- Make C2C CC profile available to all vendors of next plugtest (use only 1 profile in Europe for C2C Communication)
    - It was not managed to include to the scope C2C CC Appplication requirements.
- GPSD server per test unit, with a web interface to switch scenario, and start/stop buttons for non-static scenarios.
    - GPSD server web interface was enhanced with visualization of eqach vehicle position.
- Make sure the GPSD server provides correct speed, time and heading info.
    - This was achieved.
- Preparing the scenario per test takes a lot of time, use the upper tester interface to drive the test units? Make sure test parameters are machine readable (XML, JSON etc.)
    - In 2017 ETSI will automate the lab interop scenarios.
- Prepare IOP set-ups to test over Ethernet. Many vendors support this, and it saves a lot of hassle with attenuators and spurious messages from other teams.
    - Face-to-face setups were out of scope at Plugtest#5.
- Perhaps there should be a central "issues" white board next to the forwarding setup to write down problems with the equipment. Several testers repeatedly had to identify the same issues.
    - Forwarding was not tested at Plugtest#5.
- Scope for a next event
    - DCC (Sensitivity threshold correction, energy threshold test, header decoding test, DCC stability)
        - This feature was out of scope.
    - SPAT/MAP/IVI/SAM
        - Partly achieved through UC3 and UC5.
    - Pseudonym Change with changing GN address and Station ID
        - This feature was out of scope.

- Day one applications (including GLOSA); Test only features relevant for Day 1, e.g. no GeoUnicast, no TSB , no KeepAlive , i.e. like C2C CC Profile
    - Mostly achieved except C2C CC profile.
- More security tests for exceptional behavior of DENM and conformance of certificates
    - Security conformance test suite has exceptional behaviour implemented.
- Traces / PathHistory . Test that data is interpreted correctly
    - Not achieved.
- Include road operator in test infrastructure
    - Achieved with integration of Autostrade.
- Out of band emission
    - This feature was out of scope.
- CAM Coexistence feature
    - This feature was achieved with UC9.
- Performance / High load scenarios
    - This feature was out of scope.
- Fast Verification
    - This feature was out of scope.
- More channel simulation testing
    - This feature was out of scope.

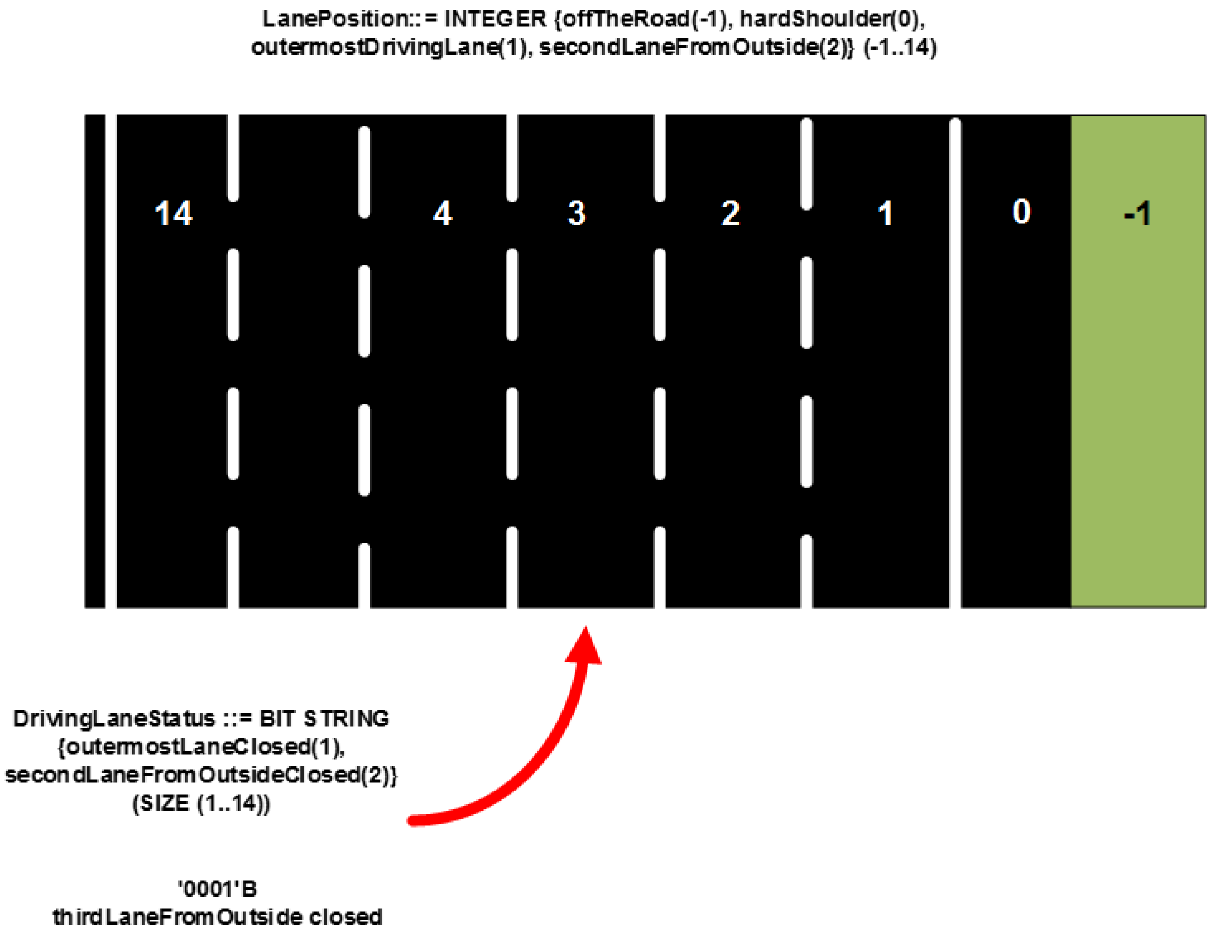
8.1 Feedback from Plugtest#5

- Indoor lab: More face-to-face testing would have been helpful.
- A central monitoring station would have enabled a more thorough validation of the frames sent on the outdoor testtrack.
- Having at least two time slot to test the same test.
- Provide all test parameters (pre-defined messages) in machine readable format and in WSG84 coordinates.
- Scope for a next event
    - Performance / High load scenarios
    - More channel simulation testing
    - Traffic Jam Use Case
    - Emergency Vehicle Use Case
    - Adverse Weather Use Case
    - EEBL Use Case
    - RTK support from RSU to OBU
    - More advanced IVI and SPAT/MAP tests
    - SERM/SSEM

- Use of the vehicular CAN bus to trigger events
- Massive amount of cars: e.g. 200 cars in sight; 20 new cars/s, 2000 messages
- Security interoperability also including BSI PKI architecture and certificates
- Internet of things enabling autonomous driving cars
- DCC (Sensitivity threshold correction, energy threshold test, header decoding test, DCC stability)

Annex A: Change Request from German Corridor Project

A.1 LanePosition and DrivingLaneStatus



A.2 NamedBitList

A.2.1 Introduction

The DrivingLaneStatus is a length-constrained BIT STRING with 'NamedBitList' and shall be encoded following rule 16.3 of X.691 (see Annex of the present document). As a consequence, the original length (2 bits) and trailing zeroes are not encoded. This means that the bit string 0100 (a road with 3 lanes + hard shoulder where only the outermost is closed) will be received as 01, as the UPER allows dropping the last 2 zeroes. The result is that the receiving cars cannot know a priori that the road is actually composed by 1 hard shoulder + 3 lanes and that the 2 leftmost are open. On the contrary, when only the innermost lane is closed (0001), then the transmitted bit string gets no modification (which allows the receiving car to have a full picture of the number of lanes of the carriageway and their driving lanes status).

To solve this inconsistency the definition could be changed
from

```
DrivingLaneStatus ::= BIT STRING {outermostLaneClosed(1), secondLaneFromOutsideClosed(2)} (SIZE (1..14))
```

to

```
DrivingLaneStatus ::= BIT STRING (SIZE (1..14))
```

This would mean that clause 22.7 does no longer apply and the clause 16.11 applies instead; which results in not removing trailing zero bits.

A.2.2 Type Change Proposal

```
ETSI TS 102 894-2 V1.2.1

Bit-Schema DEFINITIONS AUTOMATIC TAGS ::=

BEGIN

  ExampleOld ::= SEQUENCE {

  drivingLaneStatus DrivingLaneStatus

  }

DrivingLaneStatus ::= BIT STRING { outermostLaneClosed(1), secondLaneFromOutsideClosed(2) }(SIZE (1..14))

END
```

```
ETSI TS 102 894-2 next version

Bit-Schema DEFINITIONS AUTOMATIC TAGS ::=

BEGIN

  ExampleNew ::= SEQUENCE {

  drivingLaneStatus DrivingLaneStatus

  }

DrivingLaneStatus ::= BIT STRING (SIZE (1..14))

END
```

exampleOld ExampleOld ::= { drivingLaneStatus '0100'B } -> Encoded binary data 0x14 -> Decoded bitstring **'01'B**

exampleNew ExampleNew ::={drivingLaneStatus '0100'B }-> Encoded binary data 0x34 -> Decoded bitstring **'0100'B**

A.2.3 Conclusion

The two definitions encode differently, but a receiver can decode binary strings from both. Therefore there is 100% backwards compatibility on a logical level). However, there is not 100% forward compatibility as a receiver which decodes a binary string produced by an encoder following the old type definition will not get the full information of all lanes.

Backwards compatibility is the most important feature and therefore the change can be introduced without increasing the protocol version number of DENM.

The text in clause A.23 fo DENM needs to be changed to clarify the fact that the bitmap shows both open and closed lanes.