4th ITS Cooperative Mobility Services Plugtest; Helmond, NE; 17 - 27 March 2015

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

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Contents

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1 Executive Summary

ETSI‘s ITS technical committee develops standards for communications between vehicles (e.g. car-to-car), and between vehicles and fixed locations (e.g. car-to-infrastructure). ITS is scheduled to be deployed in Europe in 2019. In order to meet this goal, the European Commission has financially supported the development of ETSI’s release 1 package of ITS standards. The existence of common European standards is paramount to ensure the interoperability of ITS services and applications as well as to accelerate their introduction for the car industry and road users.

Standard development should ideally undergo a cycle of specification development, followed by validation of the specification, followed by development of standardized test specifications. ETSI implements these best practices through organizing Plugtests™ interoperability events and creating standardized test specifications.

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 TASSinternational, from 17 to 27 March in Helmond, Netherlands.

Participating companies from the automotive sector tested the interoperability of their solutions. In addition they ran tests to assess their compliance with the latest standards developed by the ETSI ITS technical committee. The event also included a field demo of selected Car-to-X Communication Use Cases, gathering experts from both public and private organizations specializing in ITS technologies and implementations.

This event aimed to test the interoperability of ITS equipment from all key vendor implementations and to validate4 the base specifications of ITS protocols CAM, DENM, GeoNetworking and Security.

As in the previous events, conformance testing was conducted in order to allow vendors to assess the level of compliance to ETSI ITS Release 1.

At the end of each day a wrap-up meeting was held to discuss main interoperability points of the day.

The implementations were connected via a test network to a GPSD server which provide for each test scenario the appropriate GPS feed. The GPSD server was provided by ETSI CTI.

ETSI CTI produced a Plugtests guide containing more than 40 interoperability tests. Also, the ETSI CTI interoperability tool suite consisting of WIKI, Scheduling Tool and Test Reporting Tool, was deployed.

More than 2600 interoperability tests were executed during the course of this event.

A high level of interoperability and maturity of the ITS technology was observed.

The Plugtest blog is accessible at http://www.etsi.org/news-events/past-events/846-plugtests-2015-itscms4?tab=3.

2 References

The following base specifications were validated in the Plugtest.

[i.1] ETSI EN 302 637-2 v1.3.2: CAM base specification

[i.2] ETSI EN 302 637-3 v1.2.2: DENM base specification

[i.3] ETSI EN 302 636-5-1 v1.2.1: BTP base specification

[i.4] ETSI EN 302 636-4-1 v1.2.1: GN base specification

[i.6] ETSI TS 102 894-2 V1.2.1: Common Data Dictionary

[i.7] ETSI TS 103 097 V1.2.1 (RCv1.1.15): Security header and certificate formats

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 Participants

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

Table 1: List of teams

#	Teams
1	**AUTOTALKS**
2	**COMMSIGNIA**
3	**COHDA /NXP**
4	**CTAG**
5	**DENSO**
6	**I-GAME**
7	**HITACHI/RENESAS**
8	**IMTECH**
9	**ITRI**
10	**KAPSCH**

11	**MARBEN**
12	**NEAVIA**
13	**NEC**
14	**NORDSYS**
15	**NOVERO**
16	**QMIC**
17	**SIEMENS**
18	**TRIALOG**
19	**UNEX**
20	**YOGOKO**
21	**VIALIS**

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

Table 2: List of test tool vendors

#	Vendor	Role
1	**COHDA**	ITS-G5 Modems for Conformance Test Setup
2	**COMMSIGNIA**	ITS-G5 Modems for Conformance Test Setup
3	**FRAUNHOFER FOKUS**	TS103 097 Web Validator
4	**FRAUNHOFER HHI**	Real Time Channel Simulation
5	**FRAUNHOFER SIT**	PKI Setup for Security Testing
6	**OCTOSCOPE**	Attenuator matrix with variable attenuation settings
7	**QOSMOTEC**	Attenuator matrix with variable attenuation settings
8	**Testing Technologies**	Conformance Test Runtime Environment
9	**Vector Informatik**	Monitoring
10	**TASS International**	Scenario simulator for OCTOSCOPE and QOSMOTEC attenuator systems

Table 3: List of represented projects

#	Project

1	**COMPASS4D**
2	**I-GAME**
3	**PRESERVE**
4	**SCOOP@F**

5 Technical and Project Management

5.1 Test Plan

The test plan containing 49 CAM, DENM, GN interoperability tests and 8 Security interoperability tests was developed by ETSI CTI together with a team of 3 experts. During the regular conference calls which were held as part of the event preparation, companies could propose additional tests. The tests were grouped in mandatory and optional tests. 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. The initial test schedule allowed for each company to test against a fair number of other companies. The 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. Within the test sessions, test slots of variable length were allocated according to the relevant test configurations.

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 9 day schedule was organized. Companies could attend either the full time or for a shorter duration (with the implication that they could only test against a limited number of companies).

5.3 Test Infrastructure

5.3.1 Central Position Server

The CPS provided a GPS feed for each of the 28 test configurations. In order to execute a test, each vendor had to connect to the CPS. The CPS was provided by ETSI CTI.

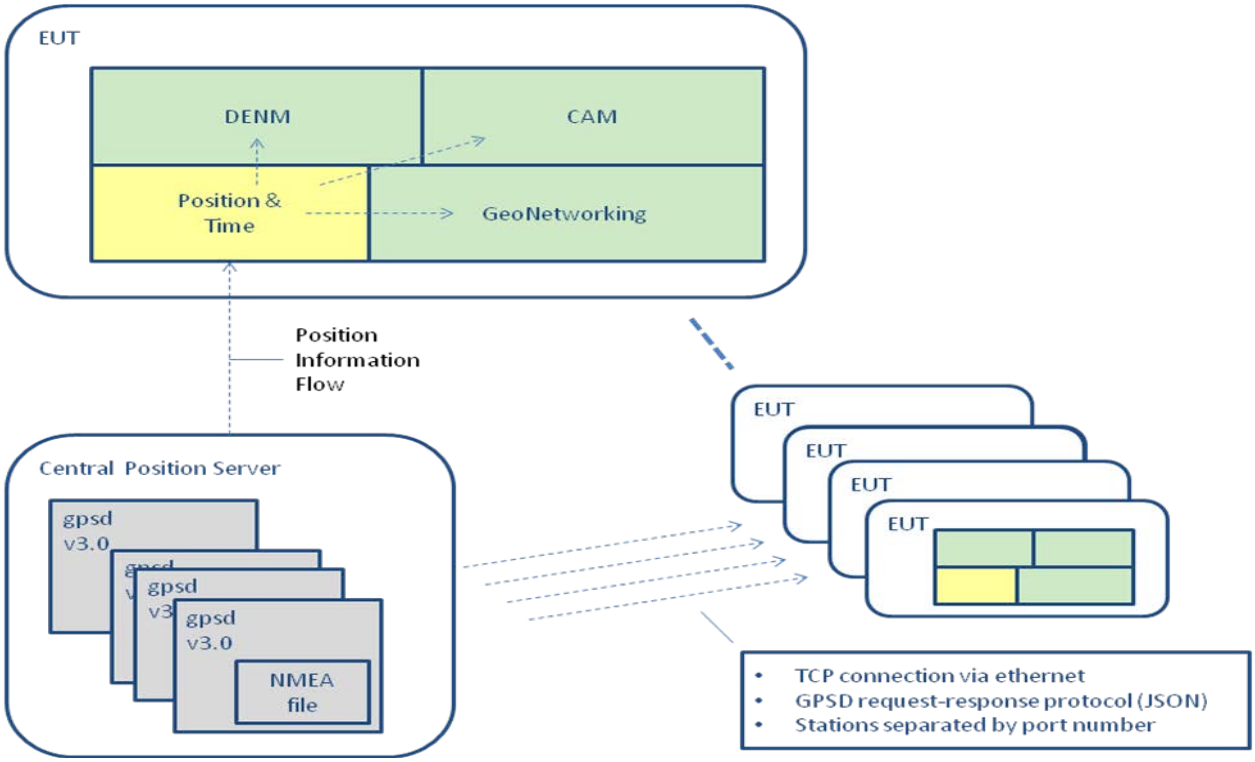

Figure 1: Central Position Server

5.3.2 Face 2 Face Configuration

The face 2 face configuration was the basic configuration used for the majority of the test. It was important to use radio cables and not to do OTA tests as there were multiple test sessions running in parallel. Each vendor had to bring its own attenuators and radio cables.

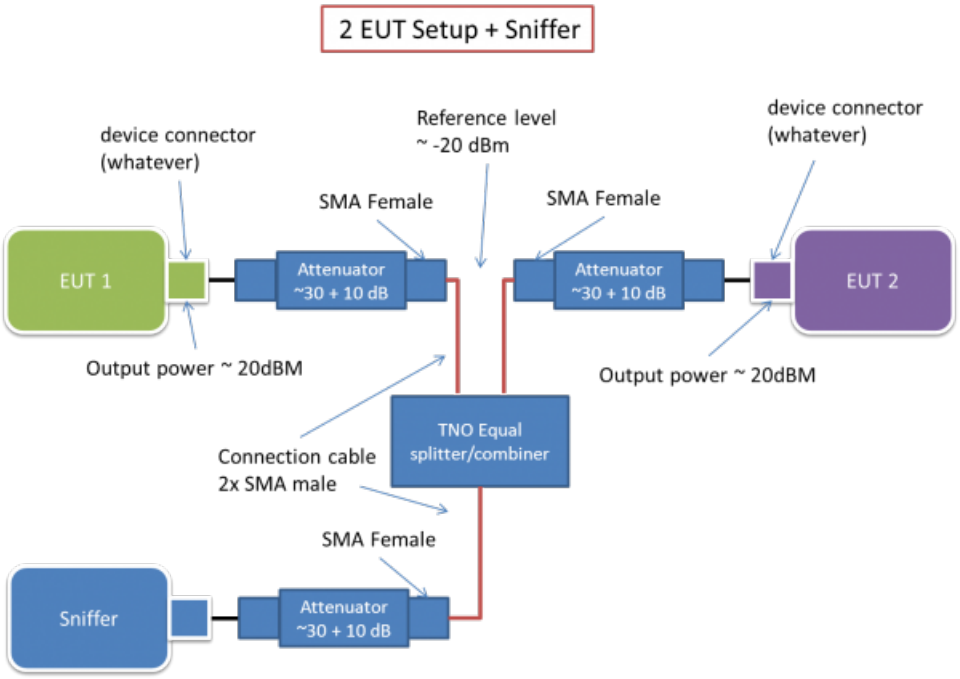

Figure 2: Face 2 Face Configuration

5.3.3 Configuration for Forwarding Scenarios

Two radio benches for testing interoperability between 3 connected devices were provided by Qosmotec. The setup of one radio bench is shown in the picture below.

For each DUT a shielding box was provided. The DUTs could be supplied with power from externally and can be controlled via Ethernet or USB. inside the shielding box, the participants had to provide a RF connector cable from their DUT to an SMA(f) connector, leading the signal out of the box.

The 3 boxes were connected to an attenuator matrix with variable attenuation settings. The attenuators were controlled by the Qosmotec QPER software providing the RF conditions for the forwarding scenarios.

The message flow between the participating DUTs was supervised by a monitor device and displayed in the Vector CANoe software.

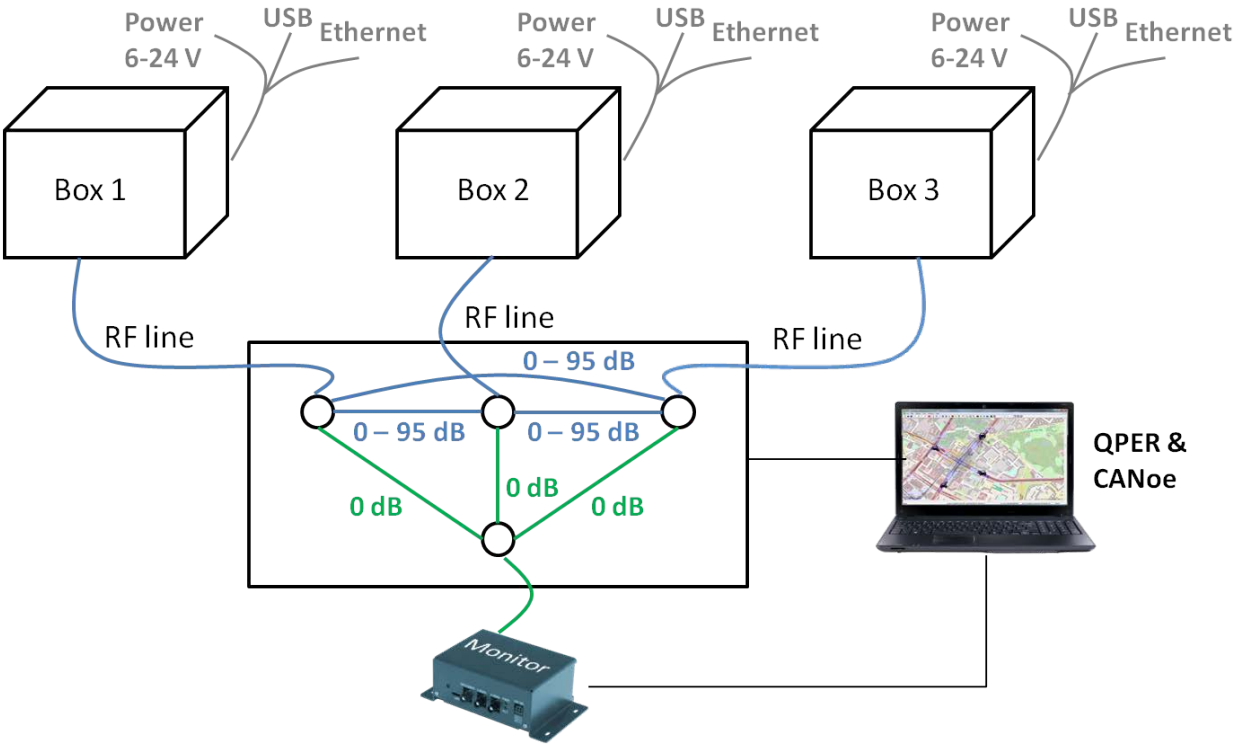

Figure 3: Configuration for Forwarding Scenarios

5.3.4 PKI Setup

The PKI setup was created for the Plugtest only by Fraunhofer SIT. Consequently, the root certificate and CA certificates were not used for other purposes. The PKI setup consisted of the following CAs as shown in the figure:

- Trusted and untrusted Root CA
- Trusted and untrusted AA

In order to perform positive tests the following certificate were provided by the PKI operator:

- The root certificate was provided as hex encoded string in separate file. The file name contained the certificate ID of the root certificate (HashedId8 according to ETSI TS 103 097 V1.1.15) and the name "RootCA".
- The certificate of the AA was provided as hex encoded string in separate file. The AA certificate contained a digest of the root CA as signer according to the draft version of ETSI TS 103 097 V1.1.15. The file name contained the certificate ID of the AA certificate (HashedId8 according to ETSI TS 103 097 V1.1.15) and the name "AA_RootDigest".

In order to perform negative tests the following certificate were provided by the PKI operator:

- Another untrusted root certificate was provided that has issued an untrusted AA certificate. This root certificate was provided as hex encoded string in separate file. The file name contained the certificate ID of the root certificate (HashedId8 according to ETSI TS 103 097 V1.1.15) and the name "RootCA_untrusted".
- The AA certificate was signed by the untrusted root CA and was provided as hex encoded string in a separate file. The AA certificate contained a digest of the untrusted root CA as signer according to ETSI TS 103 097 V1.1.15. The file name contained the certificate ID of the AA certificate (HashedId8 according to ETSI TS 103 097 V1.1.15) and the name "AA_untrusted_RootDigest".

The provided root and AA certificates followed the specifications of ETSI TS 103 097 V1.1.15 and contained the following elements:

- One uncompressed verification key and one encryption key
- One assurance level that contains the maximum value 7 = 0xE0 according to the draft version of ETSI TS 103 097 V1.1.15
- One ITS-AID list with two entries:
  - AID = 36 (CAM processor) presented as 0x24 according to Letter to CEN ISO ITS-AID change of number allocation
  - AID = 37 (DENM processor) presented as 0x25 according to Letter to CEN ISO ITS-AID change of number allocation
- One validity restriction of type "time_start_and_end". The validity of the root and the AA cert will be defined for one year.
  - Start time = 01.01.2015 UTC
  - End time = 30.4.2015 UTC
- One signer info according to the profile described in ETSI TS 103 097 V1.1.15
- One validity restriction of type "region" with a geographic region of type "none"

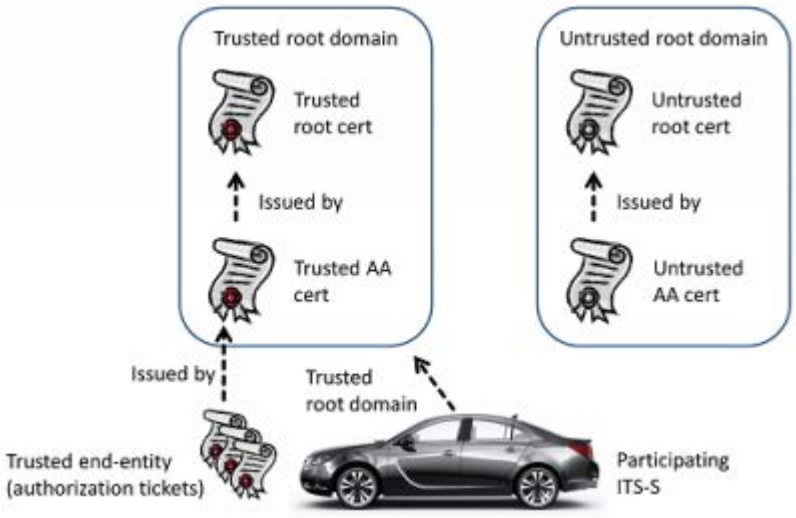

Figure 4: PKI Setup

5.4 Interoperability Test Procedure

In total five different interop areas were deployed and six test session chairs supervised the test execution. Each test was executed in the same manner as listed below:

1) Connect two or three devices from different vendors

2) Check connectivity between devices

3) Perform tests according to Plugtest Guide

4) Check if devices can send/receive frames from each other

5) Check if data is handled correctly in the network and facility layers

6) Check if implemented algorithms work correctly

7) Result determination and reporting

8) Result OK: run next test

9) Result NOK: check monitor tools to identify source of error

10) Report results in ETSI Test Reporting Tool

11) Once all tests executed swap receiver / sender roles and run all tests again

5.5 Conformance Validation Framework

The ETSI ITS Conformance Validation Framework is a test software to assess the base standard compliance of a vendor implementation. It is available as Open Source at http://forge.etsi.org/websvn/. The tests are developed in TTCN-3 (see www.ttcn-3.org) and cover the following ETSI standards:

Table 4: 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 (V1.3.1)
ETSI EN 302 637-3 v1.2.2: DENM base specification	ETSI TS 102 869-1,2,3 (V1.4.1)
ETSI EN 302 636-4-1 v1.2.1: GN base specification	ETSI TS 102 871-1,2,3 (V1.3.1)
ETSI TS 103 097 V1.2.1 (RCv1.1.15): Security header and certificate formats	ETSI TS 103 096-1,2,3 (V1.2.1)
SAE J2735 SPAT/MAP and ISO19091 (Region-D)	ETSI TS 103 191-1,2,3 (V1.1.1)

At the Plugtests a total of four test operators and four test systems was deployed based on the TTCN-3 run time environment, provided by Testing Technologies, and the ITS-G5 modems provided by Cohda Wireless and Commsignia.

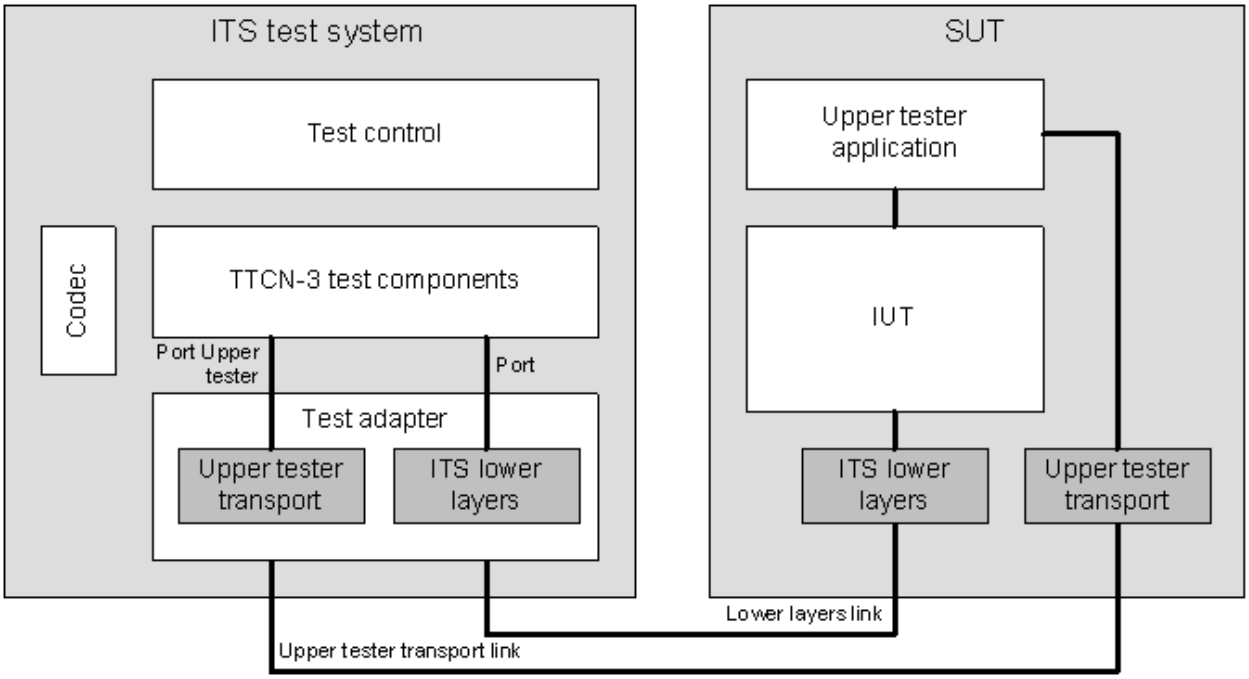

Figure 5: Conformance Validation Framework

5.6 Setups for radio level measurements

5.6.1 PHY Performance Evaluation by Fraunhofer HHI

The setup is shown in the figure below. It provided a means for Statistical Channel Emulation, based on ETSI ITS channel models, and covered the main characteristics of the doubly-selective vehicular radio channel, e.g. multipath and Doppler. Furthermore, Replay Channel Emulation based on channel measurements conducted by HHI, was provided.

The test system provided an interface to receive the DUT packet count in order to determine the packet error rate.

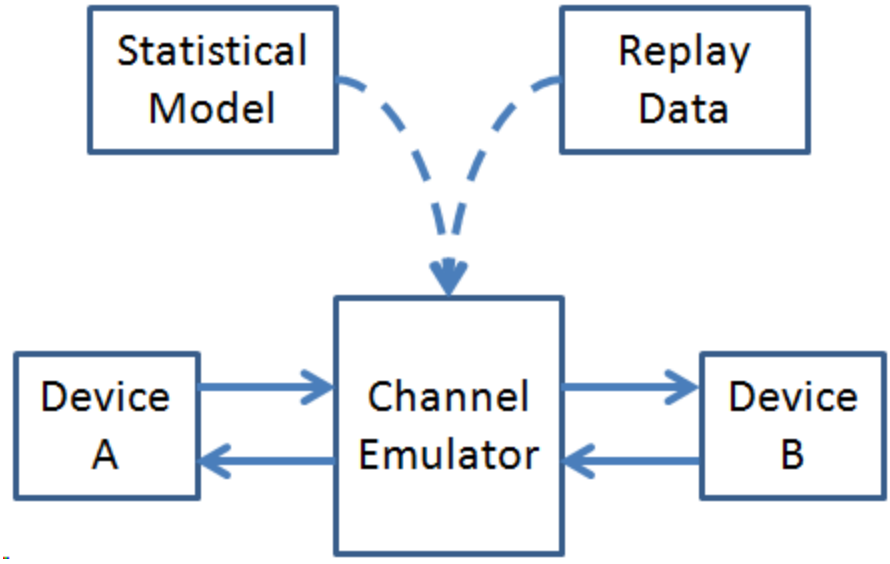

Figure 6: PHY Performance Evaluation by Fraunhofer HHI

5.6.2 Motion Emulation by octoScope/TASS/SAVARI

The setup is shown in the figure below. The test system emulated motion of vehicles and the related attenuation, while at the same time monitoring the BER performance.

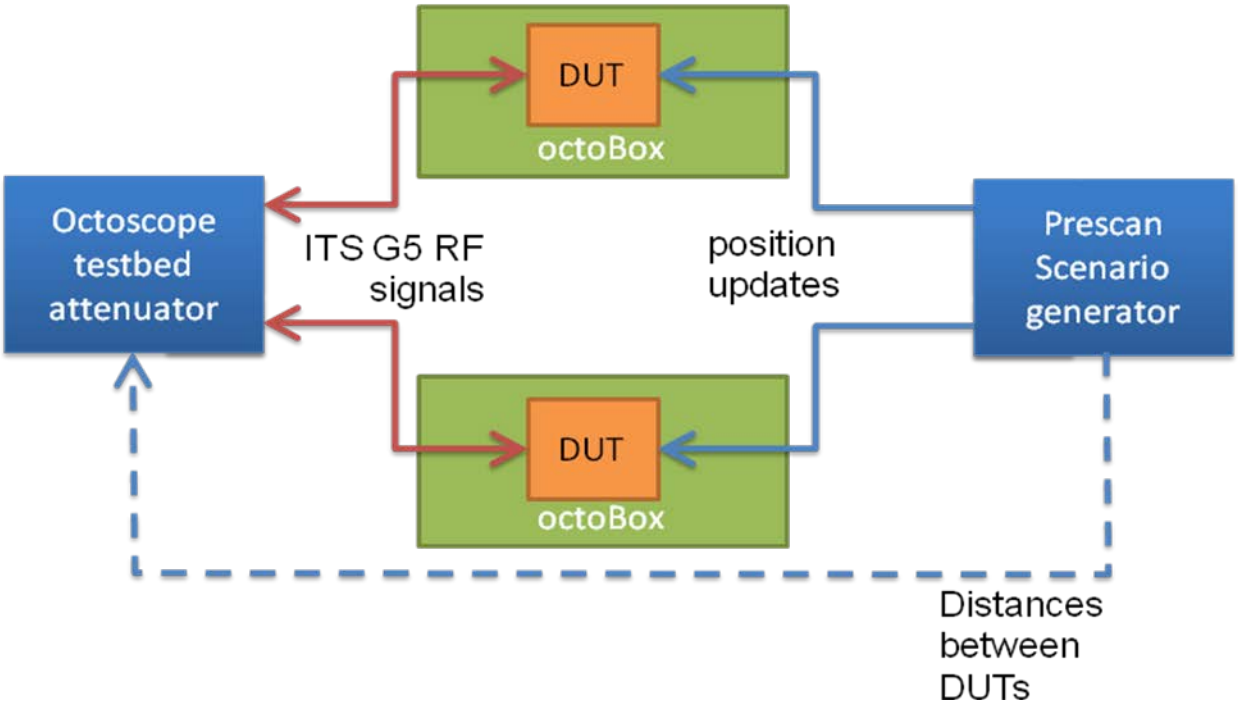

Figure 7: Motion Emulation by octoScope/TASS/SAVARI

5.6.3 Mobility Emulation Scenarios by Qosmotec and TASS

The setup is shown in the figure below. The test system emulated motion of vehicles and the related attenuation, while at the same time monitoring the BER performance.

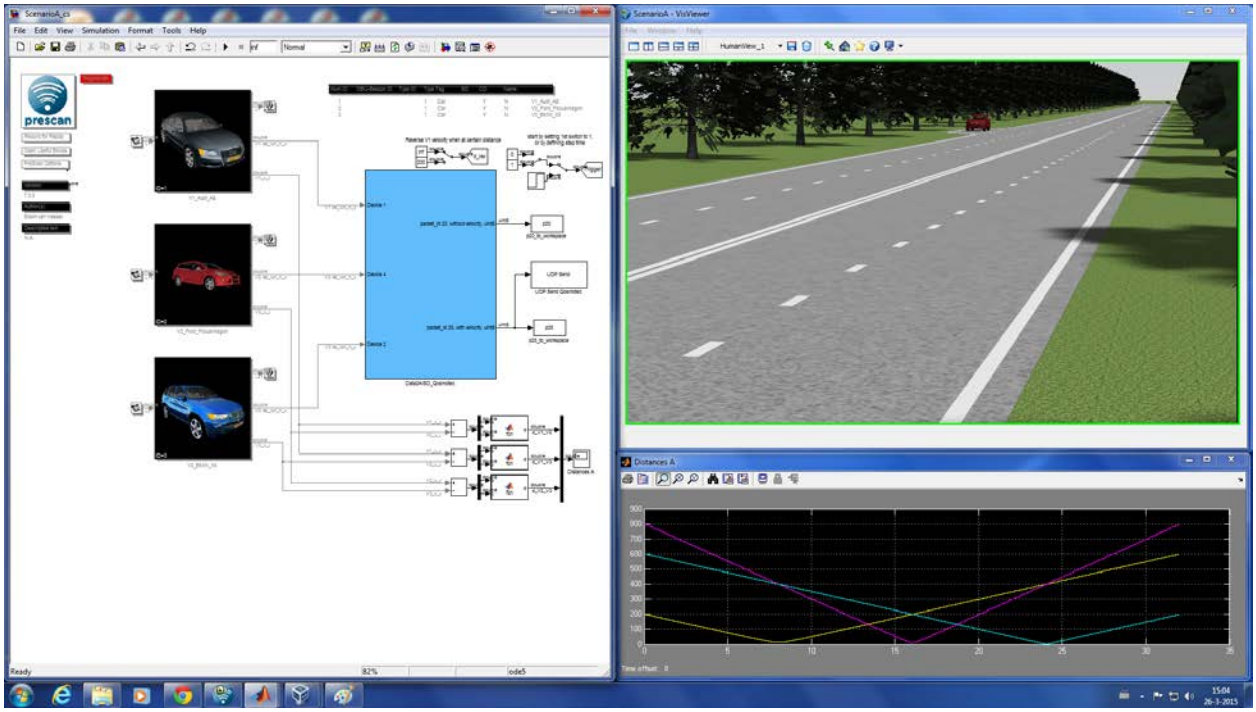

Figure 8: Mobility Emulation Scenarios by Qosmotec and TASS

6 Achieved Interoperability Results

6.1 Overview

The achieved results show that all ITS devices have been compatible on a basic level, i.e. sent data could be decoded and interpreted properly by receivers. All vendors provided ITS devices with integrated ITS G5 modems (no more SW prototypes only). Most vendors had implemented Security features, and only 22 potential issues with the ETSI ITS Release 1 were found.

In comparison to the last Plugtest in November 2013, a core group of ITS vendors has now devices which achieve excellent interoperability results.

Most of the vendors did support the test interface to the ETSI Conformance Test System which allows automated execution of the ETSI ITS Release 1 conformance tests.

This demonstrates that the ITS technology is mature and ITS devies are ready for certification and deployment.

Note: The above statements do not include results on the specific spectrum measurements defined in the harmonized standard EN 302 571 1.2.1 based on the ITS spectrum regulation in Europe.

Table 5: Results Overview of interop test for CAM, DENM, GN and Security in F2F configuration

	Interoperability		Not Executed		Totals	
	OK	NO	NA	OT	Run	Nr of tests
IOP CAM	102 (79.7%)	26 (20.3%)	24 (9.2%)	110 (42.0%)	128 (48.9%)	262
F2F DENM	6 (85.7%)	1 (14.3%)	4 (16.7%)	13 (54.2%)	7 (29.2%)	24
F2F GN	201 (80.1%)	50 (19.9%)	68 (15.7%)	114 (26.3%)	251 (58.0%)	433
F2F SEC	151 (84.8%)	27 (15.2%)	8 (3.3%)	57 (23.5%)	178 (73.3%)	243

Table 6: Results Overview of interop tests for CAM, DENM, GN and Security in 3-DUT configuration

	Interoperability		Not Executed		Totals	
	OK	NO	NA	OT	Run	Nr of tests
DENM	9 (100.0%)	0 (0.0%)	5 (12.2%)	27 (65.9%)	9 (22.0%)	41
GN	35 (59.3%)	24 (40.7%)	11 (6.2%)	107 (60.5%)	59 (33.3%)	177

Table 7: Results Overview of conformance tests for CAM, DENM, GN and Security

	Results		Not Executed		Totals	
	PASS	FAIL	NA	OT	Run	Nr of tests
CONF CAM	480 (98.4%)	8 (1.6%)	147 (22.7%)	14 (2.2%)	488 (75.2%)	649
CONF DENM	267 (93.7%)	18 (6.3%)	69 (18.8%)	13 (3.5%)	285 (77.7%)	367
CONF GN	735 (97.4%)	20 (2.6%)	182 (18.5%)	46 (4.7%)	755 (76.8%)	983
CONF SEC	464 (93.9%)	30 (6.1%)	99 (16.3%)	15 (2.5%)	494 (81.3%)	608

6.2 ETSI Plugtest Live Demo

On Wednesday 25 March 2015 participants of the Plugtest (Commsignia, Itri and Vialis) held a live demo as part of the Automotive Week. TASS provided three vehicles in which the vendors could mount their ITS devices, and two road side units were deployed on the outdoor test site. The following V2I Use Case were demonstrated:

- Road Hazard Warning
- Traffic Jam Ahead Warning

The following V2V Use Case were demonstrated:

- Approaching Emergency Vehicle

The demo was setup by the three companies and TASS within a couple of hours on teh previous days, and the demo on Wednesday ran smoothly. This short setup time of the demo is an indicator of the high level of interoperability of ITS devices available in the market. The success of the demo also 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.

Figure 9: Demo Vehicle

Figure 10: Example of an application

6.3 Interop Issues

6.3.1 GeoNetworking

- Sender Position Vector vs Source Position Vector (SePV deleted from packets but still used in algorithms)

- GBC Advanced Fwd Algorithm not often supported

6.3.2 DENM

- Keep Alive not often supported

6.3.3 CAM

No issues to report.

6.3.4 Security

No Profile 3 tests were executed due to the open base spec issue on ITS-AID usage for messages other than CAM and DENM

- Pseudonym Change needs to be defined better
- Some ITS stations could not send long packets (694 byte signed CAM including certificate chain)
    - TS 102 687 (DCC Access Layer) restricts maxPacketDuration to 0,6 msec at 6MBit/sec
- Sender CAM Certificate inclusion
        - Reaction to request and unknown digest
        - Timing
- Exceptional behavior tests very useful for vendors

7 Base Specification Validation

7.1 GeoNetworking base specification

The table below lists the discovered base spec issues of ETSI EN 302 636-4-1 v1.21.

Table 8: Discovered GN base spec issues

1	Typo in 9.3.12.2 Source operations – Issue6982
2	ambigiuous description in 9.3.8.3 Forwarder operations – Issue6983
3	error in 9.3.12.2 Source operations – Issue6984
4	DPD in 9.3.11.3 forwarder and receiver operations – Issue6985
5	GN protocol constant itsGnGeoAreaLineForwarding is set to TRUE – Issue6986
6	clock drifting – Issue6987
7	Restructure of FWD algorithm – Issue6988
8	Duplicate Packet Detection – Issue6989
9	MAC and GN ID – Issue6990

7.2 Security base specification

The table below lists the discovered base spec issues of ETSI TS 103 097 V1.2.1 (RC V1.1.20): Security header and certificate formats.

Table 9: Discovered Security base spec issues

1	Uncomplete description of creating hash for signature of secured messages – Issue6950
2	Wrong description of considering the public key algorithm in the signature of CAMs – Issue6949
3	Wrong description of considering the signer info field in the signature of CAMs - Issue6948

4	ITS-S should accept request of unrecognized AA certificate from untrusted sender – Issue6972

Table 10: Potential new features of next revision

1	Request of unrecognized AA certificate create high channel load when all receivers reply with a certificate chain – Issue6969
2	Security link between CertID and relevant IDs (Pseudonym change) – Issue6979
3	ITS-S should stop requesting an unrecognized AA certificate if the issuer of the AA certificate is untrusted – Issue6973
4	Do we need certificates in CAM each second – Issue6976
5	add example how to define time – Issue6978

7.3 DEN base specification

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

Table 11: Discovered DEN base spec issues

1	pseudonym change for active DENMs – Issue6980
2	StationID collisions - Issue6981

8 Results of Plugtest Survey

8.1 Review of organizational issues from Plugtest#2

- There was an important ramp up time of 2 days. For a next event the ramp up time should be reduced.

- For a next event it is recommended to propose to newcomers and prototype implementations to pre test 2 – 3 days before the start of the Plugtests, in order to bring them to the same stage of interoperability level.
  Action in Plugtest#3: Pre testing was not done in Plugtest#3. And the ramp up tiem was again at least 2 days. See chapter 8.2 for more details.

- The prototype implementations from this event should run in a next event all mandatory tests in the face 2 face as well as in the radio bench configurations. **Action in Plugtest#3:** This was not achieved in Plugtest#3 because the base specifications had changed too much.

- The test infrastructure worked well. However optimizations can be done, especially in the following fields:

  - For a next event it is recommended to provide more wireshark monitoring support for the face 2 face configurations.
    Action in Plugtest#3: This was realized in Plugtest#3 with the support from VECTOR monitoring stations.

8.2 Review of organizational issues from Plugtest#3

- There was a lot of interest for Security tests. The fact that 12 DUTs had security implemented exceeded the expectation (3 – 4 DUTs initially planned). This high number of DUTs would justify a Plugtest dedicated on Security only.
  Action in Plugtest#4: Instead of organizing a separate event on security, Plugtest#4 was held for nine days so as to allow for more security sessions.

- The TS 103 097 Web Validator provided by Fraunhofer FOKUS was essential for pre testing prior to the event, and has shown that more Conformance tests are needed to preprare better for a next event.
  Action in Plugtest#4: Plugtest#4 had interop as well as conformance test sessions. The conformance test sessions were a novelty introduced at Plugtest#4.

- It would be benfical to improve the ramp-up time of the plugtest. Changes to the format of the Plugtest coud be

  - New format of Plugtest with first 2 days Conformance Testing only
    Action in Plugtest#4: The first 4 days of the event had the focus on conformance testing

  - Extended Validation activities at ETSI in preparation of next Plugtest
    Action in Plugtest#4: This was not achieved

  - More rigorous compliance self- assessment by vendors before a Plugtest
    Action in Plugtest#4: This was not achieved

  - Variable time slots during the week (e.g. Extra setup/adaptation time slots of 30 minutes between the test slots could be helpful in the first days)
    Action in Plugtest#4: The scheduler tool was updated with variable time slot support

  - To make setup part on Monday is mandatory for all
    Action in Plugtest#4: This was achieved

- In general the execution rate of test was too low. Probably this is due to the fact that many test activities were scheduled during the week and time slot was too short. To eb able to have longer time slots, less topics should be included in a Plugtest. Itwas discussed whether to run two Plugtests per year with smaller scopes, rather than having one big event.
  Action in Plugtest#4: The execution rate was enhanced due to the longer duration of the event

8.3 Organizational issues 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.
- 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.
- No Security Profile 3 tests were executed due to the open base spec issue on ITS-AID
- Make C2C CC profile available to all vendors of next plugtest (use only 1 profile in Europe for C2C Communication)
- GPSD server per test unit, with a web interface to switch scenario, and start/stop buttons for non-static scenarios.
- Make sure the GPSD server provides correct speed, time and heading info.
- 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.).
- 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.
- 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.
- Scope for a next event
    - DCC (Sensitivity threshold correction, energy threshold test, header decoding test, DCC stability)
    - SPAT/MAP/IVI/SAM
    - Pseudonym Change with changing GN address and Station ID
    - 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
    - More security tests for exceptional behavior of DENM and conformance of certificates
    - Traces / PathHistory . Test that data is interpreted correctly
    - Include road operator in test infrastructure
    - Out of band emission
    - CAM Coexistence feature

- Drive Tests
- Performance / High load scenarios
- Fast Verification
- More channel simulation testing

History

Document history		
V1.1.1	18.05.2015	Stable draft