1st ITS Cooperative Mobility Plugtest;
Helmond, Netherlands;
14 - 18 November 2011

ETSI

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Contents

1 Executive Summary

The 1st ITS Cooperative Mobility Plugtest was held from 14 to 18 November 2011 in Helmond (Netherlands).

This event was co-organized by ETSI and ERTICO and hosted by TNO. It aimed to test the interoperability of ITS equipment from all key vendors implementations of ITS protocols CAM, DENM, BTP, GeoNetworking and ITS-G5.

This event required a very detailed preparation in order to provide a radio bench setup for testing multi hop scenarios and to provide GPS feed via a position server for all test scenarios.

14 companies participated in this event executing more than 750 interoperability tests.

The companies could not run all foreseen tests, but taken into account that the test guide contained 33 tests, and that all tests were to be executed bidirectional, the execution rate of 59% is a satisfying result.

90% of the executed tests indicated interoperability which shows the high level of interoperability and maturity of the ITS technology.

The highlights are that

- all implementations have been compatible on a basic level
- implementations from DRIVE C2X and eCoMove projects were interoperable
- vendor's implementations are mature enough to start interoperability testing
- GeoNetworking standard is mature (This applies to the parts of GN base standard that were covered in the plugtest)

2 Introduction

This plugtest aimed to verify the interoperability between aimed to test the interoperability of ITS equipment from all key vendors implementations of ITS protocols CAM, DENM, BTP, GeoNetworking and ITS-G5.

The implementations were connected via a test network to the Central Position Server (CPS) which provide for each test scenario the appropriate GPS feed. A radio bench setup was used for testing multi hop scenarios.

A plugtest guide was produce containing 33 interoperability tests.

The ETSI provide the interoperability tool suite of wiki, scheduling and test reporting tool.

Each day test sessions for IOP assessment were conducted. At the end of each day a wrap-up meeting was held to discuss main interoperability points of the day.

During the event the ITS Conformance Validation Framework was demonstrated and live trials against implementations were conducted.

3 Abbreviations

CAM	Cooperative Awareness Message
CPS	Central Position Server
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
RIS	ITS Roadside Station
VIS	ITS Vehicle Station
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 Acknowledgement

This is to acknowledge the effort of

- Alexandre BERGE, AMB, for the provision of the GN wireshark dissector plugins
- Andrea TOMATIS, Hitachi, for the provision of PreDrive C2X interoperability scenarios
- Ola Martin LYKKJA, Q-Free, for the pro active review of the test specification
- Paul ALEXANDER, Cohda, for the provision of the CAM, DENM wireshark plugins
- Sven KOPETZKI, Delphi, for the support in the test specification development

5 Participants

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

Table 1: List of companies

#	Company Name
1	**Cohda /NXP**
2	**CTAG**
3	**DENSO**
4	**Hitachi**
5	**Honda**
6	**ITRI**
7	**NEC**
8	**NordSys**
9	**Peek /TNO**
10	**QUWIC**
11	**Q-Free**
12	**Siemens**
13	**Vector**
14	**VTT**

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

Table 2: List of test tool vendors

#	Test Tool Vendor	Role

1	**Fokus**	Visualization of geo positions
2	**TNO**	Radio bench set-up, Spectrum Analyzer and Central Position Server
3	**Testing Technologies**	Conformance Validation Framework
4	**Vector Informatik**	Monitoring

The following FOTs were represented by the companies.

Table 3: List of FOTs

#	Test Tool Vendor
1	**DRIVE C2X**
2	**eCoMove**

6 Technical and Project Management

All the information presented in this chapter is a extract of the ETSI event wiki https://services.plugtests.net/wiki/ITS-CMS/index.php/Main_Page (Access for registered people only).

6.1 Test Plan

The test plan containing 33 interoperability tests was developed by ETSI CTI together with a team of 4 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 features covered by all tests are listed below:

- DENM
  - Expiry Handling
  - Re-transmission
  - Message encoding/decoding
  - Message interpretation
- CAM
  - Message encoding/decoding
  - Message interpretation
- GN
  - DAD
  - Caching
  - Greedy forwarding
  - SHB
  - GeoBroadcast

Table 4: Mandatory Tests

1	TD_GN_BEA_01	Detection of neighbour
2	TD_GN_SHB_01	Broadcasting of CAM messages is correctly handled
3	TD_GN_GBC_01	DENM message is processed inside its Destination Area
4	TD_GN_GBC_02	Number of re-broadcasts is correctly handled during DENM flooding
5	TD_GN_GBC_03	DENM message is not processed outside its Destination Area
6	TD_GN_GBC_04	Geo-broadcast message caching is correctly implemented
7	TD_GN_DAD_01	Resolution of duplicate Gn address scenario
8	TD_CAM_01	CAM messages with basicVehicle profile are interoperable
9	TD_CAM_02	CAM messages with emergencyVehicle profile are interoperable
10	TD_CAM_03	CAM messages with publicTransportVehicle profile are interoperable
11	TD_CAM_04	CAM messages with basicRIS profile are interoperable
12	TD_DENM_01	DENM re-transmissions are correctly received within the DENM lifetime
13	TD_DENM_02	DENM re-transmissions are not received after the DENM lifetime
14	TD_DENM_04	DENM expiry handling is correctly implemented
15	TD_UC_01	CAM messages generate and interpret the vehicle location parameter correctly
16	TD_UC_02	DENM messages generate and interpret the vehicle location parameter correctly
17	TD_UC_03	DENM messages can include parameters needed by ‘Roadworks warning’ application
18	TD_UC_04	CAM messages can include parameters needed by ‘Traffic jam ahead warning’ and ‘Slow vehicle warning’ application
19	TD_UC_05	DENM messages can include parameters needed by ‘Traffic jam ahead warning’
	TD_UC_06	DELETED
20	TD_UC_07	DENM messages can include parameters needed by ‘Car Breakdown warning’ application

Table 5: Optional Tests

1	TD_GN_FWD_01	DENM message is correctly forwarded to its Destination Area
2	TD_GN_FWD_02	DENM message is correctly geo-routed towards its Destination Area
3	TD_GN_FWD_03	DENM message geo-routing is correctly handeled when no suitable forwarder exists
4	TD_DENM_03	DENM information is kept alive as expected during its lifetime
5	TD_UC_08	CAM messages can include parameters needed by ‘Approaching emergency vehicle’ application
6	TD_UC_09	DENM messages can include parameters needed by ‘Approaching emergency vehicle’ application
7	TD_UC_10	DENM messages can include parameters needed by ‘Weather Warning (Wind)’ application
8	TD_UC_11	DENM messages can include parameters needed by ‘Emergency electronic break lights’ application
	TD_UC_12	DELETED
9	TD_UC_13	DENM messages can include parameters needed by ‘Post crash warning’ application
10	TD_UC_14	DENM messages can include parameters needed by ‘Obstacle warning’ application
11	TD_UC_15	DENM messages can include parameters needed by ‘Wrong way driving in gas stations’ application
12	TD_UC_16	CAM messages can include parameters needed by ‘Motor cycle warning’ application
13	TD_UC_17	DENM messages can include parameters needed by ‘Slow vehicle warning’application

6.2 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 which led to an initial proposal of 48 face 2 face test sessions and 16 test sessions in the radio bench. Every test slot had a duration of 4 hours. The day was organized in a morning test session from 9.00 to 13.00 and in an afternoon test sessions from 14.00 to 18.00. Up to 7 test sessions in parallel were planned.

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.

The figure below shows the preliminary version of the test schedule.

			Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Mon 14	14:00-18:00 1	First half	Radio Test			Cohda/NXP ITRI	Peek/TNO QUWIC	Hitachi Honda
			NEC Siemens DENSO	Vector NordSys Q-Free				
		Second half	NEC Siemens	DENSO Vector	NordSys Q-Free	Radio Test		
						Cohda/NXP ITRI Peek/TNO	QUWIC Hitachi Honda	
Tue 15	9:00-13:00 2	First half	Radio Test			DENSO QUWIC	Hitachi NEC	ITRI Q-Free
			Cohda/NXP Vector Honda	Siemens NordSys Peek/TNO				
		Second half	Cohda/NXP Vector	Honda Siemens	NordSys Peek/TNO	Radio Test		
						DENSO QUWIC Hitachi	NEC ITRI Q-Free	
	14:00-18:00 3	First half	Radio Test			DENSO Hitachi	Cohda/NXP Peek/TNO	NEC Q-Free
			ITRI NordSys Honda	QUWIC Siemens Vector				
		Second half	ITRI NordSys	Honda QUWIC	Siemens Vector	Radio Test		
						DENSO Hitachi Cohda/NXP	Peek/TNO NEC Q-Free	
Wed 16	9:00-13:00 4	First half	Radio Test			DENSO Siemens	NordSys QUWIC	ITRI NEC
			Q-Free Vector Honda	Peek/TNO Cohda/NXP Hitachi				
		Second half	Q-Free Vector	Honda Peek/TNO	Cohda/NXP Hitachi	Radio Test		
						DENSO Siemens NordSys	QUWIC ITRI NEC	
	14:00-18:00 5	First half	Radio Test			QUWIC Q-Free	Cohda/NXP Siemens	Honda NordSys
			Peek/TNO Vector Hitachi	ITRI DENSO NEC				
		Second half	Peek/TNO Vector	Hitachi ITRI	DENSO NEC	Radio Test		
						QUWIC Q-Free Cohda/NXP	Siemens Honda NordSys	
Thu 17	9:00-13:00 6	First half	Radio Test			Cohda/NXP NordSys	NEC Vector	ITRI QUWIC
			Hitachi Siemens Peek/TNO	Q-Free DENSO Honda				
		Second half	Hitachi Siemens	Peek/TNO Q-Free	DENSO Honda	Radio Test		
						Cohda/NXP NordSys NEC	Vector ITRI QUWIC	
	14:00-18:00 7	First half	Radio Test			DENSO Peek/TNO	Cohda/NXP NEC	Hitachi QUWIC
			ITRI Siemens Honda	Q-Free NordSys Vector				
		Second half	ITRI Siemens	Honda Q-Free	NordSys Vector	Radio Test		
						DENSO Peek/TNO Cohda/NXP	NEC Hitachi QUWIC	
Fri 18	9:00-13:00 8	First half	Radio Test			NEC QUWIC	Hitachi Peek/TNO	DENSO Q-Free
			Cohda/NXP Honda NordSys	Siemens ITRI Vector				
		Second half	Cohda/NXP Honda	NordSys Siemens	ITRI Vector	Radio Test		
						NEC QUWIC Hitachi	Peek/TNO DENSO Q-Free	

Figure 1: Preliminary Test Schedule

6.3 Test Infrastructure

6.3.1 Central Position Server

The CPS provided the GPS feed to each implementation which used dynamically this data in their Facility and GN layer implementations. The CPS was configured to provide for each Test Session (there were up to 6 Test Sessions in parallel) different geo positions in order to minimize potential interference between Test Sessions.

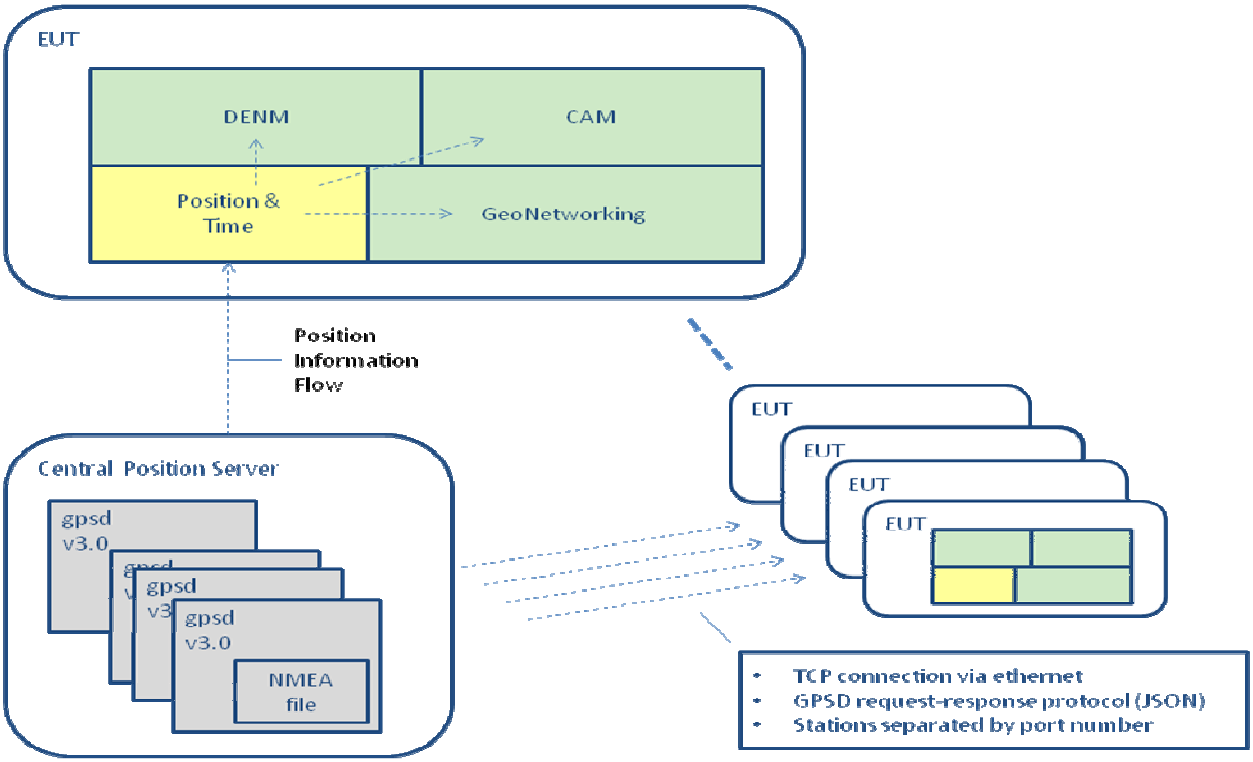

Figure 2: Central Position Server

6.3.2 FOKUS Vehicle Position Monitoring Tool

The FOKUS Vehicle Position Monitoring tool is part of a web-based tool-chain for scenario-based testing. In the context of the plugtest the tool-chain has been used to visualize the vehicle positions for tests with dynamic position updates (see tests TD_GN_FWD_02, TD_GN_FWD_03). During the whole event the tool-chain was connected to the CPS so that position updates provided by the CPS were displayed directly as vehicle positions on a map. To support different test configurations separate configuration related visualizations have been prepared and provided by separate URLs so that the test operators were able to log in to a specific configuration of the web-based tool. The visualization of the vehicle positions has been mainly used to manually synchronize the test execution with the cyclic updates of the position data from the CPS. The figure below shows a screenshot of the monitoring tool as used during the plugtest.

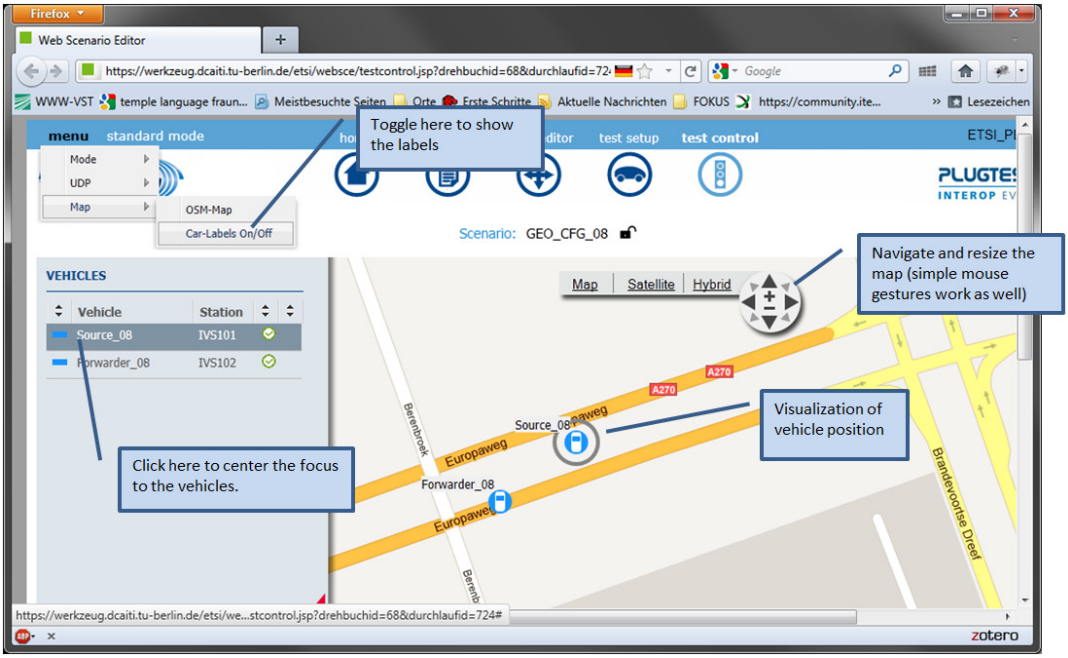

Figure 3: Vehicle Position Monitoring Tool

6.3.3 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 up to 6 test sessions running in parallel.

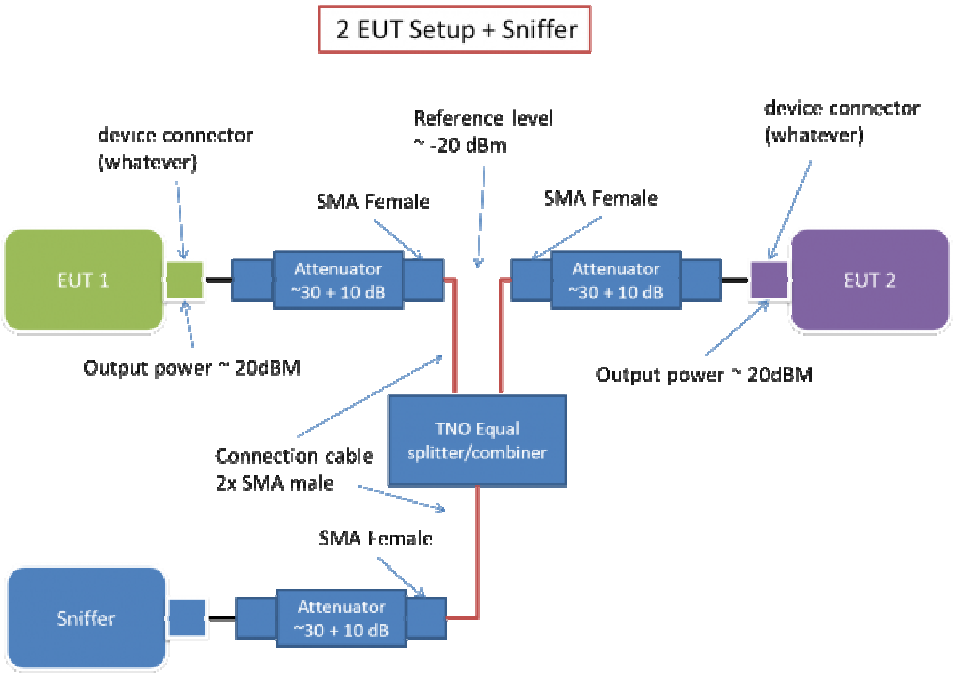

Figure 4: Face 2 Face Configuration

6.3.4 Radio Bench

The radio bench was used to test the multi hop scenarios such as 'GN Greedy forwarding' and 'GN Re-broadcast'. It was also used to test scenarios that needed specific radio attenuation such as 'GN Caching'. The Faraday cages prevented unintended RF signal leakage as data and mains were filtered and the radio devices (EUTs) were not able to radiate through the air. This forced a communication path depending on the settings of the attenuators. This enabled the

participants to exercise their tests in a controlled manner. Moreover, the relay function would otherwise have been difficult to examine in a proper way. In addition a spectrum/network analyser was used for checking the setup and to solve issues regarding RF power settings.

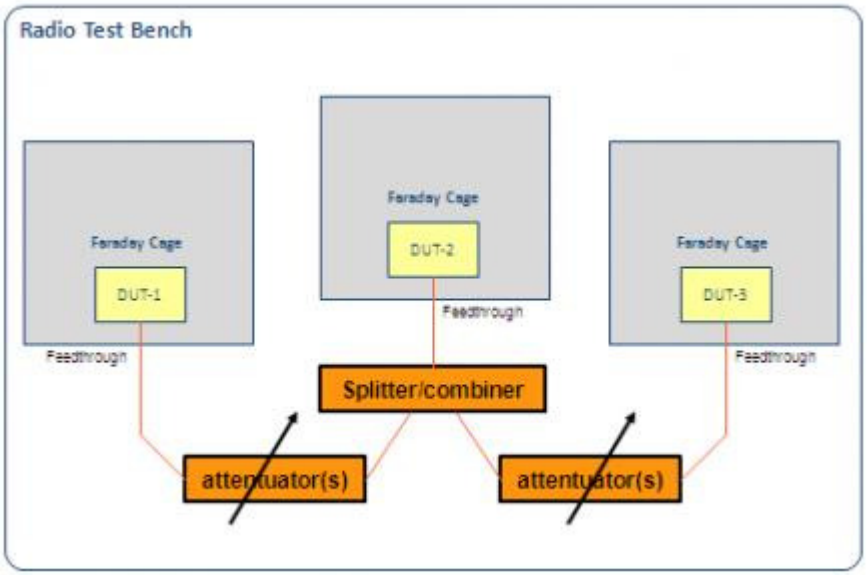

Figure 5: Radio Bench

6.4 Interoperability Test Procedure

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

7 Achieved Results

The achieved results show that all implementations have been compatible on a basic level, i.e. sent data could be decoded and interpreted properly by receivers. Furthermore the vast majority of equipment performed well on the physical layer.

However, mature and prototype implementations exist, and the difference between mature and prototype implementations is in the level of coverage of implemented features. It needs to be stated that when features were implemented, then high interoperability was observed.

During the tests sessions capture files were produced, and some snapshots of these capture files were used to run Conformance Monitoring. This exercise shows that all implementations should perform a conformance testing.

Highlights of the test sessions were that

- At least 4 companies succeeded with multi hop tests in the radio bench configuration
- DRIVE C2X and eCoMove implementations proved interoperability on a basic level

7.1 Overview of mandatory tests executed in face 2 face configurations

There were 15 mandatory tests defined which were to be executed bidirectional, i.e. each test session had to run 30 tests. In a total more than 750 tests were executed and the figure below shows the results of all tests. The mandatory tests which were to be executed in the radio bench setup are not listed (please see refer to clause 7.3).

The execution rate of 59% is a satisfying result, especially as it is a first interoperability event and given the fact that prototype and mature implementations attended.

95% of the test verdicts were PASS which shows the high level of maturity of the tested protocols.

25 % of the tests were executed due to non implemented features. The non implemented features were mainly CAM and DENM. A reason for this is the fact that both protocols are undergoing a revision. On the GN protocol the non implemented features were mainly GN DAD and GN destination area computation.

16% of the tests were not executed due to time limitation. There was a substantial ramp up time during, and almost no test session could be completed during the first 2 days. This is the main reason why tests were not executed due to time limitation.

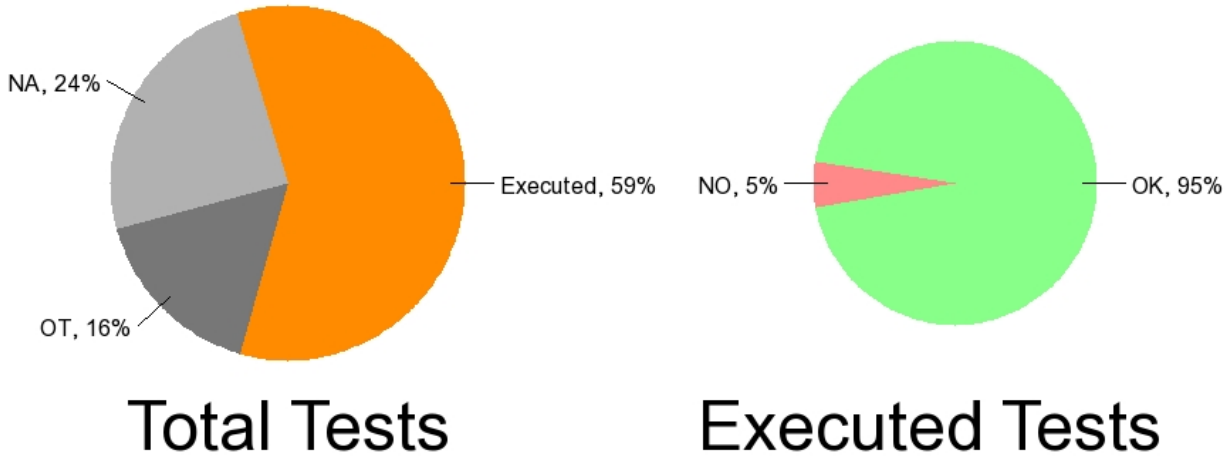

Figure 6: Results of mandatory tests

7.2 Listing of mandatory tests of face 2 face configuration

The figure below provides results per test. Please note that the mandatory tests which were executed in the radio bench (the DENM tests and some GN tests) are not listed.

		Interoperability		Not Executed		Totals
Group	Test Id	OK	NO	NA	OT	Run
Use Case	TD_UC_01	**45 (95.7%)**	2 (4.3%)	19 (22.1%)	20 (23.3%)	47 (54.7%)
	TD_UC_02	**33 (84.6%)**	6 (15.4%)	26 (30.2%)	21 (24.4%)	39 (45.3%)
	TD_UC_03	**29 (90.6%)**	3 (9.4%)	28 (32.6%)	**26 (30.2%)**	32 (37.2%)
	TD_UC_04	**37 (100.0%)**	0 (0.0%)	24 (27.9%)	**25 (29.1%)**	37 (43.0%)

	TD_UC_05	31 (96.9%)	1 (3.1%)	28 (32.6%)	26 (30.2%)	32 (37.2%)
	TD_UC_07	28 (90.3%)	3 (9.7%)	29 (33.7%)	26 (30.2%)	31 (36.0%)
CAM	TD_CAM_01	52 (88.1%)	7 (11.9%)	19 (22.1%)	8 (9.3%)	59 (68.6%)
	TD_CAM_02	51 (98.1%)	1 (1.9%)	20 (23.3%)	14 (16.3%)	52 (60.5%)
	TD_CAM_03	51 (98.1%)	1 (1.9%)	20 (23.3%)	14 (16.3%)	52 (60.5%)
	TD_CAM_04	47 (97.9%)	1 (2.1%)	22 (25.6%)	16 (18.6%)	48 (55.8%)
GeoNetworking	TD_GN_BEA_01	84 (100.0%)	0 (0.0%)	1 (1.2%)	1 (1.2%)	84 (97.7%)
	TD_GN_SHB_01	82 (97.6%)	2 (2.4%)	0 (0.0%)	2 (2.3%)	84 (97.7%)
	TD_GN_GBC_01	64 (88.9%)	8 (11.1%)	12 (14.0%)	2 (2.3%)	72 (83.7%)
	TD_GN_GBC_03	56 (100.0%)	0 (0.0%)	24 (27.9%)	6 (7.0%)	56 (65.1%)
	TD_GN_DAD_01	33 (89.2%)	4 (10.8%)	44 (51.2%)	5 (5.8%)	37 (43.0%)

Figure 7: Results per tests

7.3 Overview of other tests

The tests listed as optional focused on testing of inclusion of application specific parameters in CAM and DENM messages. Altogether 90 tests were executed and very high level of interoperability achieved. Only the mature implementations executed these tests, which explains the relative low number of tests executed.

The tests executed in the radio bench were the most complex in terms of physical configuration (3 vendors and faraday cages) and in terms of the protocol features tested, i.e. GN Caching, GN Greedy forwarding and GN Re-broadcast. Only the mature implementations had all features implemented. Only a small number of tests was executed and hence it was not meaningful to establish any statistics. However, every implementation that tried out the tests in the radio bench reported that it was useful for debugging purposes.

8 Summary of Wrap Up Sessions

8.1 IOP Issues

- 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 plugtest, in order to bring them to the same stage of interoperability level.
  - 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.
- The test infrastructure worked well. However optimizations can be done, especially in the following fields:
  - For a next event it is recommended to provide a wireshark monitoring support for the radio bench setup
  - For a next event it is recommended to provide more wireshark monitoring support for the face 2 face configurations
- The conformance monitoring of select trace probes showed that conformance testing is required
  - For a next event it is recommended to provide more conformance tests slots
- Issues were discovered with non quality ASN.1 compilers
  - For a next event it is recommended to provide reference packets so that each vendor can ensure that their implementations can correctly encode/decode the packets
- The IOP issues discovered with implementations were mainly
  - Bugs with timestamps lead to not processing received packets, i.e Time Module stuck, Bug in the software

- Bugs with destination area computation
- Output power too low, i.e. some hardware had broken power amplifiers, Malfunctioning Tx behaviour
- Choice of quality ASN.1 compiler is essential, i.e Support for extensions (e.g. , …), Support for extended integer range

8.2 Base Spec Issues

- GN protocol base spec
  Clause 8.5.2 Table 4 'Length of the Network Header payload' should be called 'Length of the GN payload' (e.g. BTP + CAM)
- GN protocol base spec
  In Table 1/MID it says: 'This field represents the LL_ADDR', Is this link needed and if yes, do we need to change the MAC address as well when we change GN address?
- GN protocol base spec
  During the tests quite varying radio performance resulting sometimes in asymmetric links (A hears B, but B does not hear A). The current GeoNetworking standard does not consider such scenarios, while they could happen in reality quite often for GeoUnicast, because greedy forwarding targets next hops at the edge of the wireless range. The next revision of the GeoNetworking standard should consider handling asymmetric scenarios, and their avoidance, for scenarios of greedy forwarding and scenarios of broadcasting cached messages
- DENM protocol base spec
  What should be the value of generationTime parameter in DENM retransmissions? (same as in original message or retransmission time)?

8.3 Test Spec Issues

- The CAM and DENM test should contain more variation. All the use cases test only the cause code. Test should be updated with more profile information
- A default frequency of 1 Hz for CAM messages should have been defined
- The Test Reporting Toll should have been configured in such a way that would have allowed to execute similar tests in sequence, i.e TD_GN_SHB_01 and TD_CAM_01 and TD_UC_01

Annex A Interoperability Test specification

The interoperability test specification, which forms parts of the present technical report, is contained in the file ITS_CMS1_Plugtest_Guide.pdf which accompanies the present document.

ITS_CMS1_Plugtest_
Guide.pdf

History

Document history		
V1.1.1	December 2012	Final version