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Architecture of ITS Interoperability Validation Framework

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

In response to EC mandate M/453 [i.6], ETSI Technical Committee (TC) ITS has standardized base and conformance test specifications for ITS protocols. In a following step a prototype TTCN-3 conformance test system was built and validated. The present document describes the design and validation of the prototype TTCN-3 interoperability test system, extending the previous prototype with interoperability features.

The action described in the present document has supported the implementation of ITS standards by:

- Making available a set of standardized interoperability test specifications for V2X Applications, CAM, DENM as well as Geonetworking functionality.
- A framework which will allow to run end-to-end interoperability test scenarios while at the same time assessing compliance of the air interface of all ITS-S devices.
- Releasing all software as open source and thus allowing industry to build and run their own interoperability validation framework.

The ITS Interoperability Validation Framework follows the principles of:

- Test automation.
- Support for various types of testing (conformance and interoperability testing).
- Flexible adaption to proprietary interfaces.

- Remote testing.
- Over-the-air interface triggering and observation.

1 Scope

The present document provides a description of the architecture of the ITS interoperability validation framework, including definition of the test environment, codec and test adapter. It provides, as well, all the necessary source code to build and run the ITS interoperability validation framework.

The ITS interoperability validation framework integrates the test suites defined in ETSI TS 103 192-3 [i.4].

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI ES 201 873-5 (V4.5.1): "Methods for Testing and Specification (MTS); The Testing and Test Control Notation version 3; Part 5: TTCN-3 Runtime Interface (TRI)".

[i.2] ETSI EG 201 015 (V2.1.1): "Methods for Testing and Specification (MTS); Standards engineering process; A handbook of validation methods".

[i.3] IEEE 802.11p™: "IEEE Standard for Local and Metropolitan Area Networks - Specific requirements; Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications; Amendment 6: Wireless Access in Vehicular Environments".

[i.4] ETSI TS 103 192-3 (V.1.1.1): "Intelligent Transport Systems (ITS); Testing; Interoperability test specifications for ITS V2X use cases; Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)".

[i.5] ETSI TR 103 099 (V.1.4.1):"Intelligent Transport Systems (ITS);Architecture of conformance validation framework".

[i.6] EC mandate M/453: "Standardisation mandate addressed to CEN, CENELEC and ETSI in the field of Information and Communication Technologies to support the interoperability of co-operative systems for Intelligent Transport in the European Community".

3 Abbreviations

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

API	Application Programming Interface
ARCI	Ambient or Road condition pictogram Class
ARNI	Ambient or Road condition pictogram Nature
AT	Authorization Ticket
ATS	Abstract Test Suite
BP	BrainPool

BTP	Basic Transport Protocol
CA	Cooperative Awareness
CAM	Cooperative Awareness Message
CC	Cruise Control
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
EC	European Commission
ETH	ETHernet
GN	GeoNetworking
HMI	Human-Machine Interface
IP	Internet Protocol
ITS	Intelligent Transportation Systems
ITS-S	Intelligent Transportation Systems - Station
IUT	Implementation Under Test
MAC	Media Access Control
MID	Mac ID
PC	Personal Computer
PDU	Protocol Data Unit
RT	Right Turn
SUT	System Under Test
TA	Test Adapter
TC	Test Cases
TRI	TTCN-3 Runtime Interface
TSB	Topology Scoped Broadcast
TSPC	Traffic Sign Pictogram Class
TSPN	Traffic Sign Pictogram Nature
TTCN-3	Testing and Test Control Notation 3
UDP	User Datagram Protocol
UT	Upper Tester

4 Test platform overview

4.1 Constraints and requirements

The purpose of the ITS test platform is to provide a reliable set of software and hardware equipment that can be used to validate TTCN-3 abstract test suites (ATS) developed in ETSI.

The architecture of this test platform has been designed with respect to the following constraints:

- to be compatible with the requirements expressed in the validation handbook (see ETSI EG 201 015 [i.2]);
- to be independent of the platform used to implement the test system (see ETSI ES 201 873-5 [i.1]);
- to be independent of the TTCN-3 tool provider;
- to be configurable and customizable;
- to provide tools and well-defined interfaces to system under test (SUT), allowing test automation;
- to be easily extensible for future ITS protocols;
- to provide generic components that can be reused in other test platforms.

In addition, great care has been taken to separate ITS specific functionalities from generic test platform tasks in order to provide a maximum number of reusable components for future test platforms.

4.2 General architecture

Typically, a TTCN-3 test platform is composed of four different components:

- The TTCN-3 test tool providing necessary software to execute the abstract test suites.
- The hardware equipment supporting TTCN-3 test execution and adaptation to SUTs.
- The codecs which convert protocol messages into their abstract TTCN-3 representation.
- The Test Adapter (TA) implementing interfaces with the device under test.

The interaction of these components is described in figure 1.

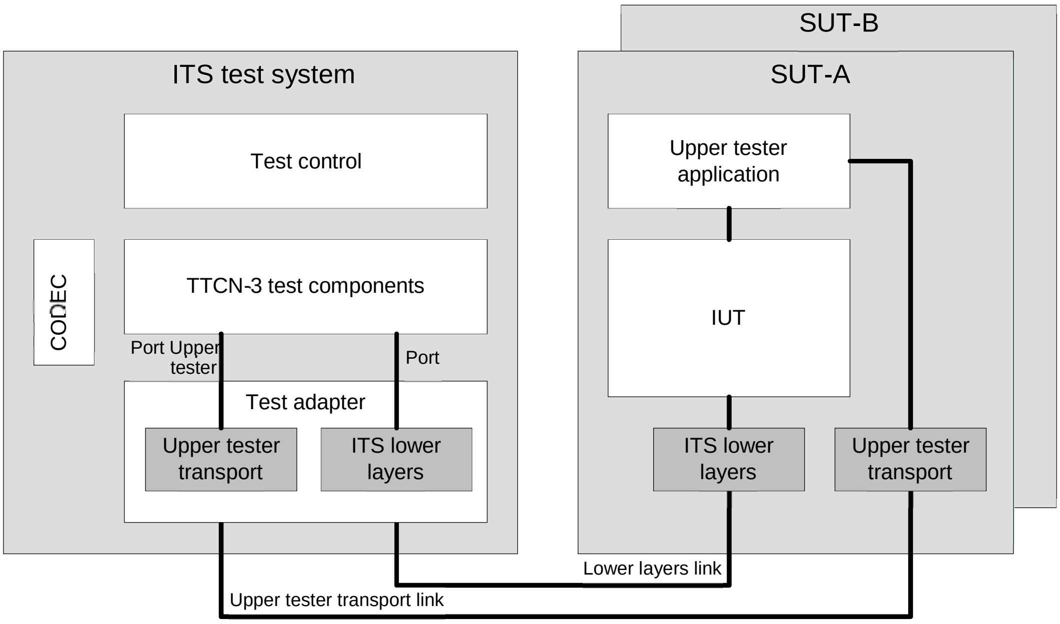

Figure 1: General architecture

The TTCN-3 test tools are usually provided by commercial companies and their description is out of the scope of the present document. The implementation details of the other components are described in the present document.

4.3 Interoperability-specific architecture

In order to handle multiple equipment under test in interoperability scenarios, each SUT is managed by a TTCN-3 test component. Protocol messages exchanged between SUTs are captured by the Test System and mimicked as internal messages between the TTCN-3 components. Figure 2 illustrates this mechanism in the case of CAM messages exchanged amongst 2 SUTs.

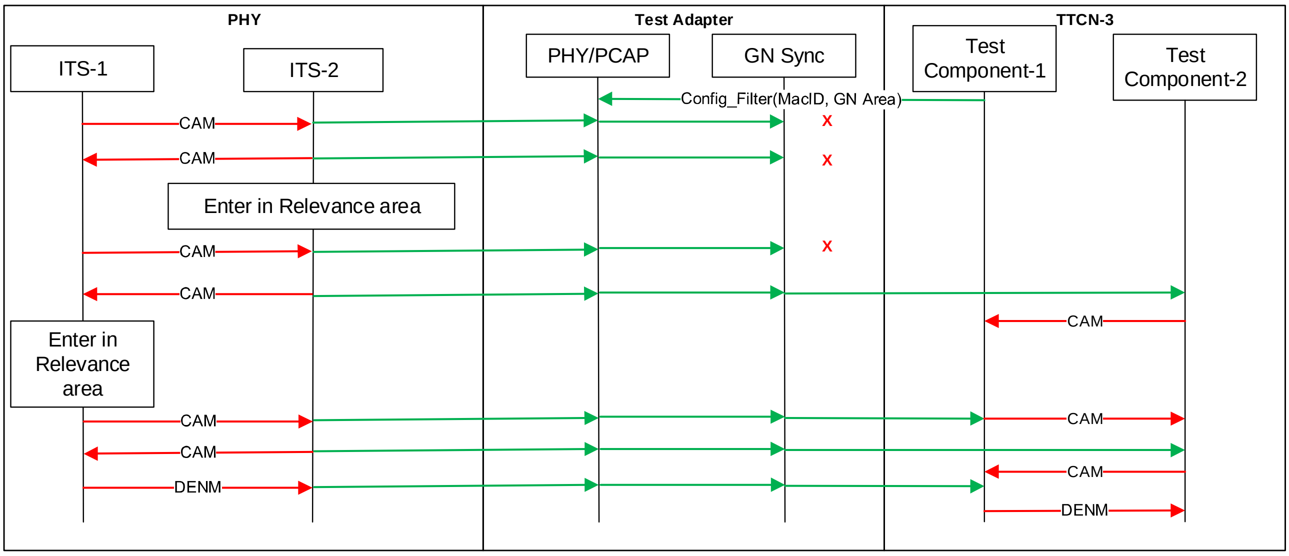

Figure 2: TTCN-3 mapping of interoperability scenario

The Test Adapter plays a very important role in this architecture as it is responsible for filtering and dispatching captured messages to the adequate component. Configuration of filtering and dispatching rules are performed during the testcase initialization phase.

5 Hardware equipment

5.1 Introduction

As an extension of the TTCN-3 conformance test system, the Interoperability Validation Framework reuses all the hardware specifications defined in ETSI TR 103 099 [i.5].

5.2 PC

The main hardware component of the ITS test platform is a standard PC. Its role is to host the execution of the test suites using a commercial TTCN-3 test tool.

Whatever operating system is installed on the computer, it is necessary to ensure that the following points are considered:

- No firewall interference with traffic generated by the Test System and/or SUT;
- Excellent time synchronization between the SUT and the test system;
- Test system processes (especially the test adapter) need to be granted unrestricted control to telecommunication hardware.

Time synchronization is maybe the most critical point to be checked before starting any test session, as it can be the source of strange SUT behaviour and generate incoherent results. Indeed, most ITS protocol messages feature a time tag used by the receiver to determine if the information it carries is still valid; if the test system is ahead in time, all messages it sends will be considered either as coming from the future or from a very old date and will be discarded.

This PC is equipped with two network cards, one being used for ITS communication with SUT (lower layers link), the other one being used for exchanging upper tester messages (upper tester transport link). Separating these two communications on different hardware interfaces is not an absolute necessity, but it is a good practice and it ensures that there will be no interaction between the flows.

The communication between the SUT and the test system is achieved through Ethernet if the SUT supports it or using a G5 adaptation box, as shown in figure 3 and in figure 4.

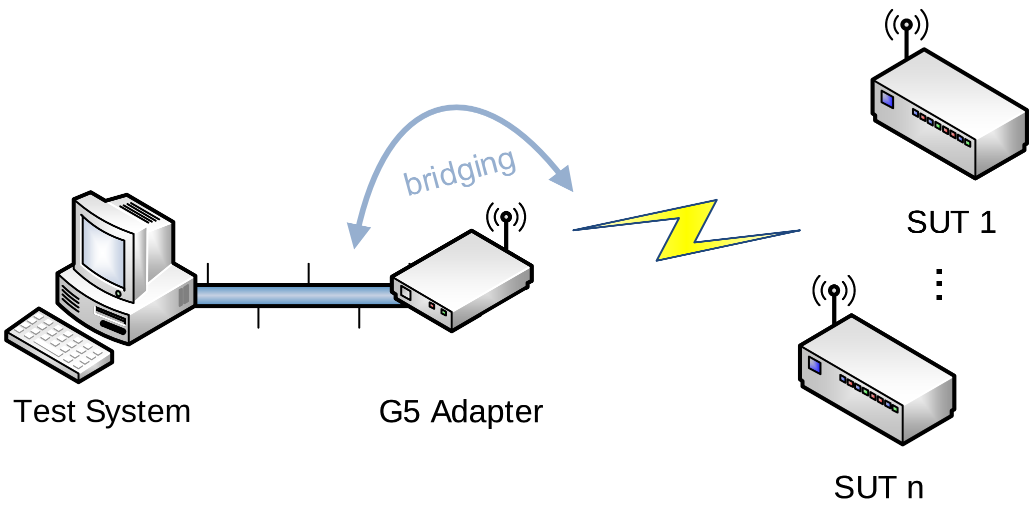

Figure 3: Communication via G5 adaptation box

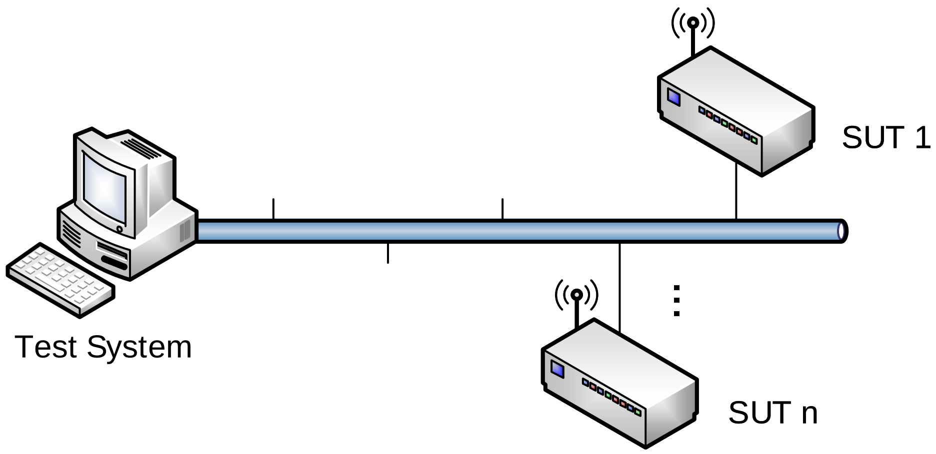

Figure 4: Communication via Ethernet

5.3 G5 switch

The ITS protocol stack makes use of G5 radio protocol (IEEE 802.11p [i.3]) in order to establish communication between ITS devices. To achieve G5 connectivity, a dedicated hardware equipment needs to be added to the test platform. The role of this G5 switch is to handle all radio-related tasks transparently and to act as a bridge for the test system, as depicted in figure 3.

6 Codecs

As an extension of the TTCN-3 conformance test system, the Interoperability Validation Framework reuses all the codec designs defined in ETSI TR 103 099 [i.5].

7 Test Adapter

7.1 Introduction

As an extension of the TTCN-3 conformance test system, the Interoperability Validation Framework reuses all the test adapter designs defined in clause 7 of ETSI TR 103 099 [i.5].

7.2 Lower Tester

Void.

7.3 Platform Adapter

7.3.0 General

As an extension of the TTCN-3 conformance test system, the Interoperability Validation Framework reuses all the test adapter designs defined in clause 7.3 of ETSI TR 103 099 [i.5].

7.3.1 Layer pcap_layer

Table 1 below describes the parameters available and their default values for the pcap_layer.

NOTE: The pcap_layer is a terminal layer, it is not possible to add another lower layer after it.

Table 1: List of pcap_layer parameters

Parameter	Description	Default value
mac_src	Source MAC address	N/A
mac_dst	Broadcast MAC address	FFFFFFFFFFFF
nic	Local Network Interface Card. If set, online mode is used, otherwise, offline mode is configured	N/A
filter	Pcap filter (compliant with tcpdump syntax) E.g. filter=and ether src 04e548000001	N/A
file	File to read (offline mode)	(empty)
frame_offset	Frame offset, used to skip packets with frame number < frame_offset (offline mode)	0
time_offset	Time offset, used to skip packets with time offset < time_offset (offline mode)	0
save_mode	Set to 1 to save sent packet, 0 otherwise (offline mode)	0

```
Example: Online mode
system.*.params := "PCAP(mac_src=4C5E0C14D2EB,nic=eth1,file=,filter=and not ether src DC536045AF7E
and ether proto 0x8947)"
Example: Offline mode
system.*.params :=
"PCAP(mac_src=BABEBABE0002,nic=,file=../../../testdata/test_61_beacon_sec.pcap,filter=and ether
proto 0x8947,frame_offset=0,save_mode=0)"
```

7.3.2 Layer ethernet_layer

Table 2 below describes the parameters available and their default values for the ethernet_layer.

Table 2: List of ethernet_layer parameters

Parameter	Description	Default value
mac_src	Source MAC address	N/A
mac_dst	Broadcast MAC address	FFFFFFFFFFFF
eth_type	Ethernet type	8 947

```
Example: system.*.params := "ETH(mac_src=F8CAB8083918)/PCAP(…)"
```

7.3.3 Layer gn_layer

Table 3 below describes the parameters available and their default values for the gn_layer.

Table 3: List of gn_layer parameters

Parameter	Description	Default value
ll_address	GeoNetworking address of the Test System	N/A
latitude	Latitude of the Test System	0
longitude	Longitude of the Test System	0
beaconing	Set to 1 if GnLayer starts beaconing	0
expiry	Beaconning timer expiry: expiry (ms)	1 000
device_mode	Set to 1 if the layer encapsulates upper layer PDU	0
secured_mode	Set to 1 if message exchanges are signed	0
encrypted_mode	Set to 1 if message exchanges are encrypted (For signed & encrypted message exchanges, both secured_mode and encrypted_mode are set to 1)	0
certificate	Certificate identifier that the Test Adapter uses	(empty)
secure_db_path	Path to the certificates and keys storage location	(empty)
hash	Hash algorithm to be used when secured mode is set. Authorized values are SHA-256 or SHA-384	SHA-256
signature	Signature algorithm to be used when secured mode is set. Authorized values are NISTP-256, BP-256 and BP-384	NISTP-256
cypher	Cyphering algorithm to be used when secured mode is set. Authorized values are NISTP-256, BP-256 and BP-384	NISTP-256

```
Example: Online mode
system.geoNetworkingPort.params :=
"GN(ll_address=4C5E0C14D2EB,latitude=43551050,longitude=10298730,beaconing=1,expiry=500,device_mode=
0,its_aid=141,secured_mode=1,ce\rtificate=CERT_TS_A_AT,sec_db_path=/home/vagrant/tmp/test_01,encrypt
ed_mode=0,cypher=NISTP-
256)/ETH(mac_src=4C5E0C14D2EB,mac_bc=FFFFFFFFFFFF,eth_type=8947)/PCAP(mac_s\rc=4C5E0C14D2EB,nic=eth1
,file=,filter=and not ether src DC536045AF7E and ether proto 0x8947,frame_offset=0,save_mode=0)"

Example: Offline mode
system.geoNetworkingPort.params :=
"GN(ll_address=F8CAB8083918,latitude=43551050,longitude=10298730,beaconing=1,expiry=1000,its_aid=141
,secured_mode=1,certificate=CE\RT_TS_A_AT,sec_db_path=/home/vagrant/tmp/Yann)/ETH(mac_src=F8CAB80839
18,mac_bc=FFFFFFFFFFFF,eth_type=8947)/PCAP(mac_src=BABEBABE0002,nic=,file=../../../testdata/test_\61
_beacon_sec.pcap,filter=and ether proto 0x8947,frame_offset=0,save_mode=0)
```

7.3.4 Layer btp_layer

Table 4 below describes the parameters available and their default values for the btp_layer.

Table 4: List of btp_layer parameters

Parameter	Description	Default value
type	btpA or btpB	btpB
destination_port	destination port	2 001
source_port	source port	0
device_mode	Set to 1 if the layer encapsulates upper layer PDU	0

```
Example: system.*.params := "BTP(destination_port=2002)/GN(…)/ETH(…)/PCAP(…)"
```

7.3.5 Layer cam_layer

Table 5 below describes the parameters available and their default values for the cam_layer.

Table 5: List of cam_layer parameters

Parameter	Description	Default value
next_header	btpA or btpB (overwrite BTP.type)	N/A
header_type	tsb|gbc	N/A
header_sub_type	sh (single hop)	N/A

```
Example: system.*.params :=
"CAM(next_header=btpB,header_type=tsb,header_sub_type=sh)/GN(…)/ETH(…)/PCAP(…)"
```

7.3.6 Layer denm_layer

Table 6 below describes the parameters available and their default values for the denm_layer.

Table 6: List of denm_layer parameters

Parameter	Description	Default value
next_header	btpA or btpB (overwrite BTP.type)	N/A
header_type	tsb|gbc	N/A

```
Example: system.*.params :=
"CAM(next_header=btpB,header_type=tsb,header_sub_type=sh)/GN(…)/ETH(…)/PCAP(…)"
```

7.3.7 Layer udp_layer

Table 7 below describes the parameters available and their default values for the udp_layer.

NOTE: The pcap_layer is a terminal layer, it is not possible to add another lower layer after it.

Table 7: List of udp_layer parameters

Parameter	Description	Default value
dst_ip	Destination IPv4 address (aa.bb.cc.dd)	N/A
dst_port	Destination port	N/A
src_ip	Source IPv4 address (aa.bb.cc.dd)	N/A
src_port	Source port	N/A

7.3.8 Layer specific

Void.

7.4 Upper Tester

7.4.0 General

As an extension of the TTCN-3 conformance test system, the Interoperability Validation Framework reuses all of the test adapter designs defined in clause 7.4 of ETSI TR 103 099 [i.5].

7.4.1 Layer ut_cam

Table 8 below describes the parameters available and their default values for the CA message upper tester layer.

NOTE: The ut_cam is a terminal layer, it is not possible to add another lower layer after it.

Table 8: List of ut_cam layer parameters

Parameter	Description	Default value
loopback	Set to 1 when the IUT does not provide an Upper Tester interface as specified in ETSI TR 103 099 [i.5] and the present document	0

```
Example: system.utPort.params :=
"UT_CAM(loopback=0)/UDP(dst_ip=192.168.1.250,dst_port=12345,src_ip=192.168.1.253,src_port=12345)/ETH
(mac_src=080027d2b658,mac_dst=90fd61e61902\,eth_type=0800)/PCAP(mac_src=080027d2b658,nic=eth1,filter
=and udp port 12345)"
```

7.4.2 Layer ut_denm

Table 9 below describes the parameters available and their default values for the DEN message upper tester layer.

NOTE: The ut_denm is a terminal layer, it is not possible to add another lower layer after it.

Table 9: List of ut_denm layer parameters

Parameter	Description	Default value
loopback	Set to 1 when the IUT does not provide an Upper Tester interface as specified in ETSI TR 103 099 [i.5] and the present document	0
station_id		

```
Example: system.utPort.params :=
"UT_DENM(loopback=0)/UDP(dst_ip=192.168.1.250,dst_port=12345,src_ip=192.168.1.253,src_port=12345)/ET
H(mac_src=080027d2b658,mac_dst=90fd61e61902\,eth_type=0800)/PCAP(mac_src=080027d2b658,nic=eth1,filte
r=and udp port 12345)"
```

7.4.3 Layer ut_gn

Table 10 below describes the parameters available and their default values for the GeoNetworking upper tester layer.

NOTE: The ut_gn is a terminal layer, it is not possible to add another lower layer after it.

Table 10: List of ut_gn layer parameters

Parameter	Description	Default value
loopback	Set to 1 when the IUT does not provide an Upper Tester interface as specified in ETSI TR 103 099 [i.5] and the present document	0

```
Example: system.utPort.params :=
"UT_GN(loopback=0)/UDP(dst_ip=192.168.1.250,dst_port=12345,src_ip=192.168.1.253,src_port=12345)/ETH(
mac_src=080027d2b658,mac_dst=90fd61e61902\,eth_type=0800)/PCAP(mac_src=080027d2b658,nic=eth1,filter=
and udp port 12345)"
```

7.4.4 Support for HMI in Upper Tester

The upper tester is used to interact with the upper interface of the implementation under test (IUT). The present document extends the Upper Tester interface defined in ETSI TR 103 099 [i.5] with API messages defined in annex C.

Annex A: Codecs Source Code

The codec source code is available at the following link:

http://forge.etsi.org/websvn/listing.php?repname=ITS.ITS&path=/releases/TR103099/v1.4.1

Annex B: Test Adapter Source Code

The test adapter source code is available at the following link:

http://forge.etsi.org/websvn/listing.php?repname=ITS.ITS&path=/releases/TR103099/v1.4.1

Annex C: Upper Tester HMI Message Format

C.1 HMI Primitives

C.1.1 HmiNeighborEventInd

This message is used to indicate detection of a new neighbor into the Location table.

Request (HmiNeighborEventInd UT ➔ TS):

0 0 1 2 3 4 5 6 7	1 0 1 2 3 4 5 6 7	2 0 1 2 3 4 5 6 7	3 0 1 2 3 4 5 6 7
MessageType = 0xC0	MID		
…			StationID
…			

Name	Length	Value
MessageType	1 byte	0xC0
MID	6 bytes	The MID value as defined in GN protocol
StationID	2 bytes	The station identifier

C.1.2 HmiSignageEventInd

This message is used to indicate signage information displayed by the HMI.

Request (HmiSignageEventInd UT ➔ TS):

0 0 1 2 3 4 5 6 7	1 0 1 2 3 4 5 6 7	2 0 1 2 3 4 5 6 7	3 0 1 2 3 4 5 6 7
MessageType = 0xC0	CountryCode		TSPC
TSPN	ARCI	ARNI	

Name	Length	Value
MessageType	1 byte	0xC1
CountryCode	2 bytes	Country code
TrafficSignPictogramClass (TSPC)	1 byte	Traffic Sign Information
TrafficSignPictogramNature (TSPN)	1 byte	Traffic Sign Nature Information
AmbientOrRoadConditionPictogramClass (ARCI)	1 byte	Ambient/Road Condition Information
AmbientOrRoadConditionPictogramNature (ARNI)	1 byte	Ambient/Road Nature Information

Annex D: Test System usage

D.1 General

Clauses D.2 to D.4 present some configurations to execute various ITS ATSs.

D.2 CA message Test Suite with an IUT non-secured

The configuration below is applied to execute the AtsCAM test suite against an IUT non-secured, which provides an implementation of the Upper Test interface as describes in ETSI TR 103 099 [i.5] and the present document.

Layers	Parameters
pcap_layer	PCAP(mac_src=080027D2B658,nic=eth1,filter=and ether proto 0x8947)
ethernet_layer	ETH(mac_src=080027D2B658,eth_type=8 947)
gn_layer	GN(ll_address=4C5E0C14D2EA,latitude=43551050,longitude=10298730,distanceA=1 500,distanceB=1 500,angle=0,beaconing=0,device_mode=1)
btp_layer	BTP(type=btpB,dst_port=2001,src_port=0,device_mbode=1)
cam_layer	CAM(next_header=btpB,header_type=tsb,header_sub_type=sh)

D.3 CA message Test Suite with an IUT secured

The configuration below is applied to execute the AtsCAM test suite against an IUT secured, which provides an implementation of the Upper Test interface as describes in ETSI TR 103 099 [i.5] and the present document.

Layers	Parameters
pcap_layer	PCAP(mac_src=080027D2B658,nic=eth1,filter=and ether proto 0x8947)
ethernet_layer	ETH(mac_src=080027D2B658)
gn_layer	GN(ll_address=4C5E0C14D2EA,latitude=43551050,longitude=10298730,distanceA=1 500,distanceB=1 500,angle=0,beaconing=0,device_mode=1,secured_mode=1,certificate=CERT_IUT_F_AT,sec_db_path=/home/vagrant/tm\p/test_01)
btp_layer	BTP(type=btpB,dst_port=2001,src_port=0,device_mbode=1)
cam_layer	CAM(next_header=btpB,header_type=tsb,header_sub_type=sh)

D.4 DEN message Test Suite with an IUT non secured

The configuration below is applied to execute the AtsCAM test suite against an IUT non secured, which provides an implementation of the Upper Test interface as describes in ETSI TR 103 099 [i.5] and the present document.

Layers	Parameters
pcap_layer	PCAP(mac_src=080027D2B658,nic=eth1,filter=and ether proto 0x8947)
ethernet_layer	ETH(mac_src=080027D2B658,eth_type=8 947)
gn_layer	GN(ll_address=4C5E0C14D2EA,latitude=43551050,longitude=10298730,distanceA=1 500,distanceB=1 500,angle=0,beaconing=0,device_mode=1)
btp_layer	BTP(type=btpB,dst_port=2 001,src_port=0,device_mbode=1)
denm_layer	DENM(next_header=btpB,header_type=tsb)

History

Document history		
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