



C-ITS CROSS-BORDER TESTING AND VALIDATION CONCEPT VERSION 3.0.0

C-Roads Platform

Working Group 2 Technical Aspects

Taskforce 5 Cross-Testing and Validation

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Publication History

Table 1 Publication History

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Index

Acronyms.....	4
Glossary	5
References.....	7
1. Introduction.....	8
1.1. C-Roads platform for harmonisation of C-ITS deployment	8
1.2. Story board C-Roads C-ITS deployment documentation.....	9
1.3. Scope of this document.....	10
2. Scope	12
2.1. Definitions and Limitations.....	12
2.2. Relevance to the EU Compliance Assessment report [C-Roads Compliance Assessment].....	13
2.3. Relevance to the ETSI Interoperability report [IoT Interop BP]	14
2.4. Scope of TF5 for hybrid communications.....	15
3. Framework.....	17
3.1. Introduction.....	17
3.2. Test-subject	17
3.3. Requirement-categories.....	17
3.4. Test-type.....	18
3.5. Test-environment.....	18
3.6. Test case	18
3.7. Test-result.....	22
3.8 Common template for reporting.....	23
4. Process.....	24
4.1. Introduction.....	24
4.2. Analysis and description	24
4.3. Test execution	28
4.4. On-Road Data Logging	28
4.5. Test results collecting process.....	28
4.6. Virtual testing session organisation	29
Appendix.....	30
A.1. Example of TF3 requirements analysis.....	30
A.2. Example of TF2 requirements analysis.....	31
A.3. Example of TF1 requirements analysis.....	31

Acronyms

Table 2 Acronyms

Term	Meaning
BI	Basic Interface
C-ITS	Cooperative ITS
CAM	Cooperative Awareness Message
DENM	Decentralized Environmental Notification Message
ETSI	European Telecommunications Standards Institute
GLOSA	Green Light Optimal Speed Advisory
HLN	Hazardous Locations Notifications
HMI	Human Machine Interface
IVIM	In-Vehicle Information Message
IVS	In Vehicle Signage
ITS	Intelligent Transport Systems
ITS-G5	ITS-G5 is a European standard for ad-hoc short-range communication of vehicles among each other (V2V) and with Road ITS Stations (V2I). ITS-G5 refers to the approved amendment of the IEEE 802.11 (standard IEEE 802.11p). This technology (possibly others) uses the 5.9 GHz frequency band to support safety- and non-safety ITS applications. In this document ITS-G5 stands for IEEE802.11p/ETSI ITS-G5.
ITS-S	ITS Station
MAPEM	MAP (topology) Extended Message
MS	Member State
OBU	On-board Unit
PCAP	Packet Capture
R-ITS-S	Roadside ITS Station (the so-called RSU)
RSU	Roadside Unit
RWW	Road Works Warning
SPATEM	Signal Phase And Timing Extended Message
SUT	System Under Test
UC	Use case
V-ITS-S	Vehicle ITS Station (the so-called OBU)
Vro	Vehicle of Road Operator

Glossary

Table 3 Glossary

Term	Meaning	Source
Certification	Certification ensures that a product can legitimately claim to have implemented a standard correctly.	[IoT Interop BP]
Compliance Assessment	Compliance assessment is an activity that helps to directly or indirectly identify the extent, to which vehicle or its constituent parts comply with the set of technical requirements, which must be validated to make the C-ITS station operational. From an operational point of view, compliance assessment is an equipment authorization issued by a compliance assessment body based on representations and test data submitted by the applicant.	[C-Roads Compliance Assessment]
Conformance assessment	Conformance assessment means checking that products, materials, services, systems or people measure up to the relevant reference specifications and standards.	[C-Roads Compliance Assessment]
Conformance testing	Conformance testing involves connecting a device to a test system and operating a set of stringently defined tests. This ensures that a (single) product implements the requirements laid down in a standard correctly.	[IoT Interop BP]
Conformity assessment	Conformity assessment shall mean the process demonstrating whether specified requirements relating to a product, process, service, system, person or body have been fulfilled. In this report this term can be considered a less stringent synonym of compliance assessment.	[C-Roads Compliance Assessment]
Conformity / Compliance Testing	Conformance testing is the process used to determine whether a product or system complies with the requirements and/or functional reference specifications.	[C-Roads Compliance Assessment]
Declaration of Conformity	Declaration of Conformity is the conclusive step of a procedure where a responsible party makes measurements or takes other necessary steps to ensure that the equipment complies with the appropriate technical standards.	[C-Roads Compliance Assessment]
(Functional) Evaluation	Assessing whether the system fulfills the intended business and functional needs.	
Individual approval	Approval of an individual vehicle instead of a type approval. On the basis of [C-Roads MSP], individual approval can only be applied to specific categories of vehicles like vehicles designed and constructed for use by the armed services, civil defense, fire services and forces responsible for maintaining public order.	[C-Roads Compliance Assessment]
Interoperability testing	Interoperability testing involves connecting devices from different vendors and operating them in a variety of real-life scenarios.	[IoT Interop BP]
(Technical) Testing	Evaluating the system's compliance with the specified technical requirements.	
Type approval	Type approval is the confirmation that production samples of a design (i.e., the type of vehicle or simply the model of a vehicle) will meet specified performance standards. The specification of the product is recorded and only that specification is approved.	[C-Roads Compliance Assessment]

Term	Meaning	Source
Validation	Validation is a core concept of the document.	
Verification	Verification is a procedure where the manufacturer makes measurements or takes the necessary steps to ensure that the equipment complies with the appropriate technical standards.	[C-Roads Compliance Assessment]

References

All references that are used in this document are defined in the C-Roads_WG2_References document.

All normative references within a standard referenced in this document are automatically included and will not be listed separately.

1. Introduction

1.1. C-Roads platform for harmonisation of C-ITS deployment

The C-Roads Platform is a joint initiative of European Member States and road operators for testing and implementing C-ITS services in light of cross-border harmonisation and interoperability. Through the C-Roads Platform, authorities and road operators join together to harmonise the deployment activities of cooperative intelligent transport systems (C-ITS) across Europe. The goal is to achieve the deployment of interoperable cross-border C-ITS services for road users.

C-ITS enables vehicles to interact directly with each other and the surrounding road infrastructure. In road transport, C-ITS typically involves vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. In order to enable an efficient and undisturbed exchange of information within these services as well as a cross-border implementation, harmonised C-ITS specifications are indispensable. The approach starts from a functional perspective, then requirements applicable to all implementations and then towards technology specifications of currently validated implementations (ITS-G5 for short range communication, IP based for long range cellular). In order to meet these challenges, the C-Roads platform is divided into five Working Groups. The first Working Group is concerned with organisational tasks, the second with Technical Aspects and the third with Evaluation and Assessment. The fourth Working Group is about Urban C-ITS Harmonisation and Working Group 5 is about Digital Transport Infrastructure (DTI).

The C-Roads Platform is steered by the C-Roads Steering Committee which is composed by Member State representatives. With the support of the Supporting Secretariat, decisions for achieving the goal of the implementation of interoperable end-user services are taken. In this respect, specifications, plans and reports, which are proposed and recommended by specific Working Groups, are approved. Within WG2 these specifications are harmonised in 5 Task Forces and derived from pilot activities and the basis for further pilot and implementation activities. This especially goes with technical decisions, which influence deployment and procurement decisions at pilot sites.

The Working Groups are installed as decision support for the Steering Committee to ensure proper decisions towards interoperable deployments. Individual experts participating in the single pilots work together in these Working Groups to prepare proposals and recommendations. Also, members of the single pilot activities as well as of the C-Roads-Working Groups actively contribute to the work of the EU-C-ITS-Platform.



Figure 1: Overview of C-Roads coverage

1.2. Story board C-Roads C-ITS deployment documentation

This document is part of the C-Roads C-ITS Deployment Documentation and Requirements. The complete set of documents is much related to a common project life cycle of a system implementation. As a guide to the C-Roads Documentation, a story board based on such a project life cycle is provided in this section, with emphasis on role of this document *C-ITS Cross-Border Testing and Validation Concept*. The story board should be read from left to right and shows the different stages of the project life cycle and how each C-Roads Documentation is related to it, thereby can be supportive to road authorities and other stakeholders.

A complete description of the story board of a C-ITS implementation project, the different stages and the related C-Roads documents is given in *Introduction to the C-Roads WG2 Deployment Documentation and Requirements*.

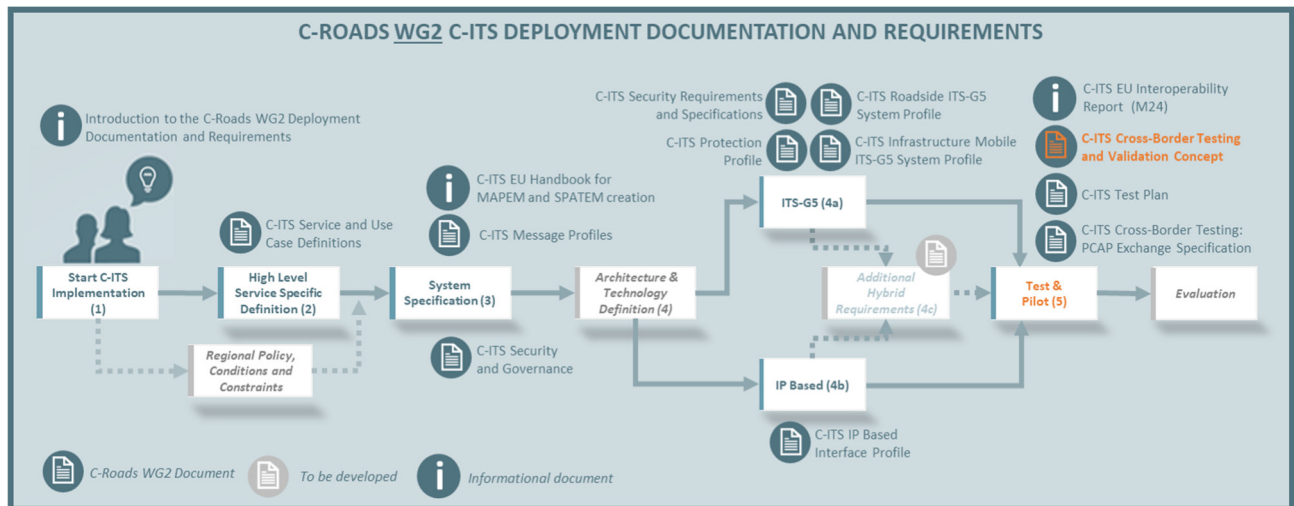


Figure 2: Highlight of WG2 document in complete storyboard

The documents cover a wide range of aspects related to several stages as described in section 1.4 of *Introduction to the C-Roads WG2 Deployment Documentation and Requirements*. Starting with stage 3, generic requirements and the required governance are specified - those are applicable for all services, use cases and scenarios in a similar way. On stage 4a and 4b, the more detailed specifications are relevant - including service specific security requirements. Both levels, generic and specific requirements, have impact on the test cases derived on stage 5.

1.3. Scope of this document

This document is one of the deliverables of Taskforce 5 of Working Group 2 of the C-Roads Platform and contributes to stage 5 in the C-Roads workflow. The stage 5 deliverables provide the basis to validate the interoperability of a C-ITS implementation and guide through all aspects of interoperability testing for ITS-G5 systems, IP-Based communication and security elements, as specified by Working Group 2 of the C-Roads Platform by the different other Task Forces, namely TF1, TF2, TF3 and TF4.

This document describes the overall concept for interoperability testing. Another stage 5 deliverable denoted “C-ITS Test Plan” contains the individual and detailed test cases. One further deliverable of stage 5, the “C-ITS Cross-Border Testing: PCAP Exchange Specification” contains a common procedure to execute one step of the methodology introduced in this document.

C-ITS is based on vehicle to vehicle communication and communication between vehicle and physical and/or digital infrastructure.

To ensure that this works in a European, multi-operator and multi-vendor environment, it is important to ensure interoperability. It is well-known from other systems that a way to ensure this is through compliance assessment. The objective of this report is to issue recommendations on how this compliance assessment can be performed.

The present release of this document guides through all aspects of interoperability testing for ITS-G5 systems, hybrid communication and security elements, as specified by Working Group 2 of the C-Roads Platform.

The flowchart below visualizes the full scale of C-Roads interoperability testing as recommended by Taskforce 5. Details and definitions of specific elements from the Figure 3 will be provided in the upcoming chapters.

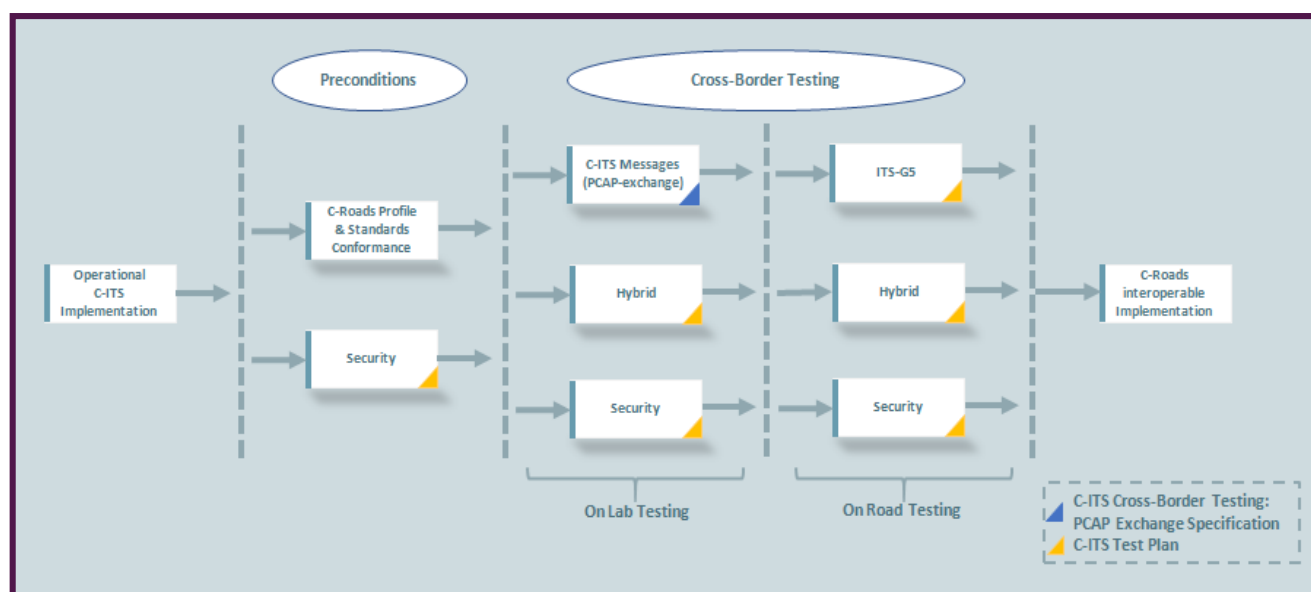


Figure 3: Overview on C-Roads interoperability testing

The second chapter provides a clear scope and necessary distinctions for the interoperability testing of C-Roads.

The third chapter elaborates on the framework of interoperability testing, as established by Taskforce 5, like common definitions for test-setups and templates for test cases and documentation.

The last chapter documents the processes how the testing requirements were derived and provides recommendations for the test execution.

2. Scope

2.1. Definitions and Limitations

Cross-border Testing and Validation focuses on describing how to, based on the C-Roads Profiles, assess cross-border interoperability of implementations of C-ITS systems.

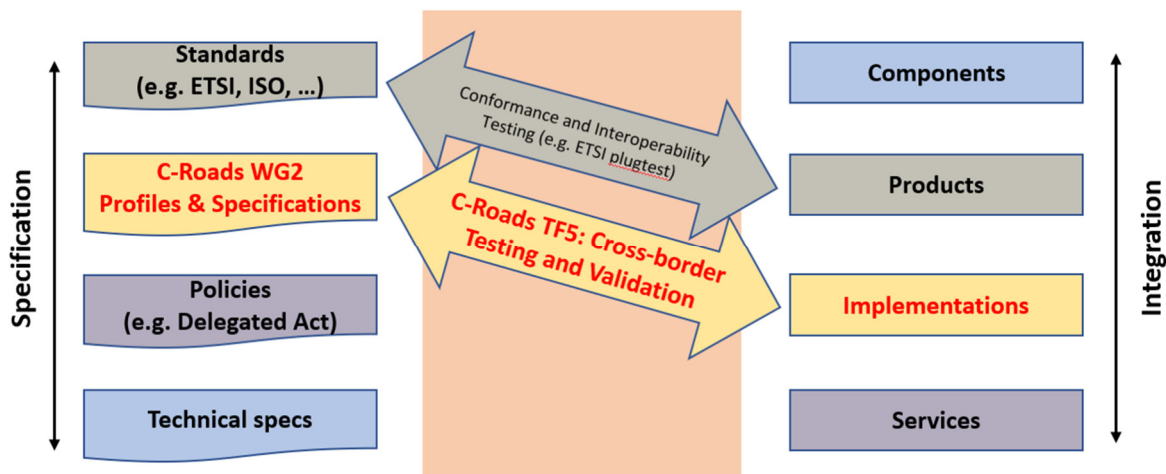


Figure 4: Scope of C-Roads WG2/TF5

The scope of the task of Taskforce 5 is limited to:

- **Road operator.** Being part of the C-Roads Platform, the scope of TF5 only includes the road operator and infrastructure aspect of C-ITS for roadside systems and mobile systems.
- **Profiles & Specifications.** TF5 focuses on the C-Roads WG2 profiles and specifications (i.e. C-Roads Common C-ITS Service and Use Case Definitions [C-Roads SUD], C-Roads Functions and Specifications [C-Roads MP], C-Roads Roadside ITS-G5 System Profile [C-Roads RSP] and the specification for interoperability of IP-based C-ITS communications [C-ITS IP Based Interface Profile].), only, not on the underlying standards and specifications. It is assumed that compliance to these underlying standards and specifications has already been assessed separately.
- **Test specifications.** The scope of TF5 does not include executing and performing actual tests, nor does it include type approval or certification. TF5 only provides specifications of tests.
- **Interoperability.** TF5 looks at the ability of end-to-end C-ITS system implementation to operate C-ITS services with foreign C-ITS-Ss, without any (re)configuration or action (e.g. a RSU from country A exchanges C-ITS messages with an OBU from country B). TF5 does not look at conformance testing as defined by ETSI [IoT Interop BP] nor does TF5 look at the quality of the implementation itself.
- **Implementations.** TF5 focuses on implementations of C-ITS systems only, not on individual products, equipment or components. It is assumed that the underlying products, equipment and/or components have already been tested separately and previously. Note that products are assumed to have already passed conformance tests on product level. Note also that the ETSI Plugtests also focus on interoperability but on a product- rather than on an implementation-level. The scope of TF5 thus goes beyond the ETSI Plugtest, from product to implementation.
- **Testing and Validation.** TF5 focuses exclusively on the (technical) verification and validation of systems, and not on the specification, set-up or operation of tests, nor on the (functional) assessment. The HMI can be used for validation and does not form part of the technical testing as it is vendor specific and may vary for different pilot sites. Other tools can also be used for validation. C-Roads have not defined what the HMI shall look like.

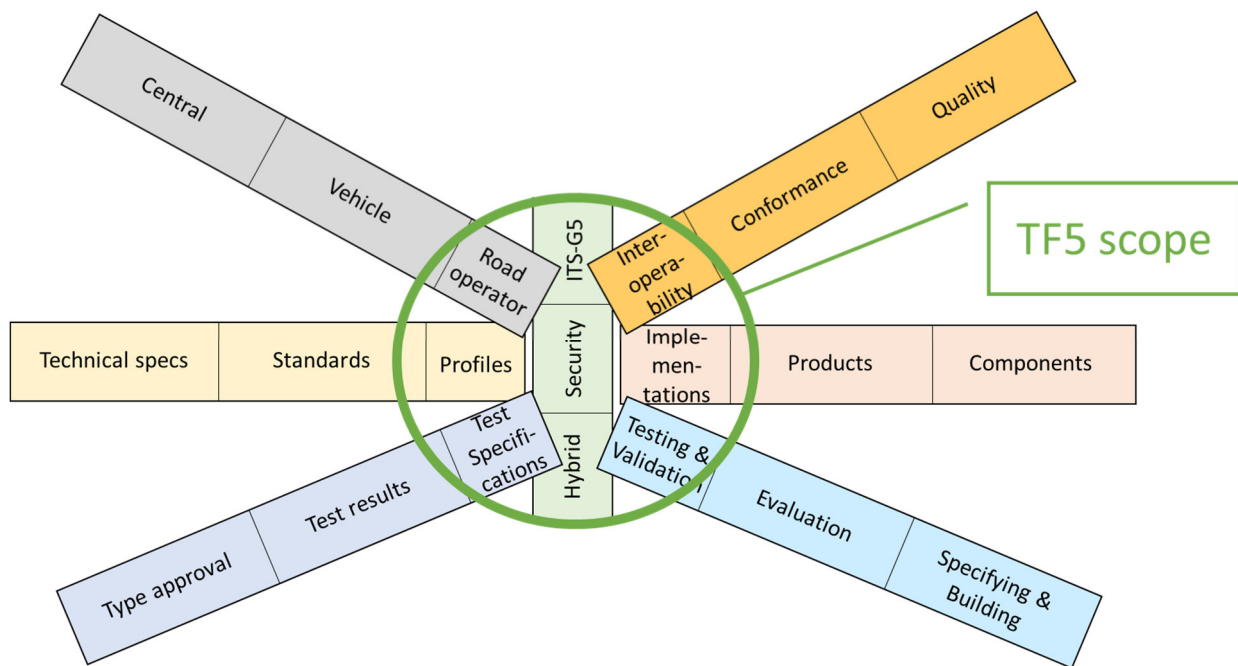


Figure 5: Limitations of the scope of TF5

2.2. Relevance to the EU Compliance Assessment report [C-Roads Compliance Assessment]

The EU report [C-Roads Compliance Assessment] describes compliance assessment as follows.

“The methodology for validation should make it possible that C-ITS services are perceived by the end user the same way for the same C-ITS application, and at the same time efforts for testing and validation are minimal for all C-ITS station operators / manufacturers and service providers involved.

In this context, the generic overarching term “compliance assessment” is used, since other terms such as “type approval” or “certification” might lead to pre-conclude on specific forms of compliance assessment (which might already be established in the road transport sector).”

- **“Compliance/conformance testing.** Compliance/conformance testing aims to determine whether a C-ITS Station complies with the relevant standards and reference specifications.
- **Interoperability testing.** Interoperability testing aims to test two or more implementations of a set of standards and reference specifications at C-ITS station level in their communication capabilities against each other and see if they work as expected.
- **End-to-end functional testing.** For end to end functional testing procedures other settings of the validation scheme and expected outcomes apply which need to be discussed with the main stakeholders in the C-ITS domain and need to make sure that the initial start of C-ITS introduction is according to the users expectations and takes into account the future extensions of applications and C-ITS units in operation. This will be achieved within the C-ROADS platform where the single work groups can elaborate a set of common documents for the national implementations and take into account mutual acceptance.”

Although the terminology is confusing, the scope of TF5 relates to ‘End-to-end functional testing’ according to the report [C-Roads Compliance Assessment]. ‘Compliance/conformance testing’ and ‘Interoperability testing’ relate more to products whereas the ‘End-to-end functional testing’ relates to implementations and refers to C-Roads.

Related to the compliance assessment process as described in the EU Compliance Assessment report [C-Roads Compliance Assessment] the scope of TF5 can be defined as given by the green circle in the figure below.

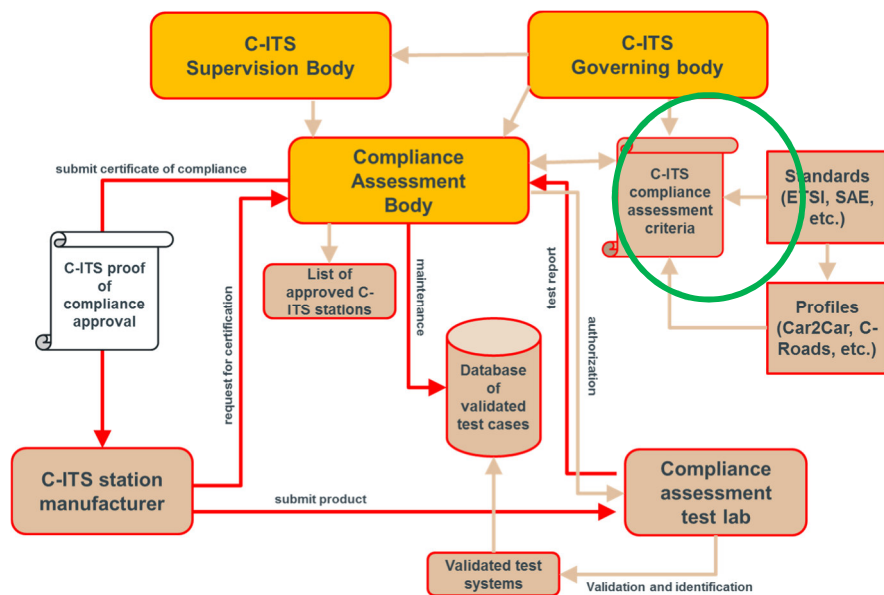


Figure 6: Overview of the compliance assessment process [C-Roads Compliance Assessment]

2.3. Relevance to the ETSI Interoperability report [IoT Interop BP]

The ETSI report [IoT Interop BP] defines interoperability as follows and warns for 'options'.

"There is no single definition of interoperability that will satisfy all readers. The following statement can be found at Wikipedia: Interoperability is a property of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, without any restricted access or implementation."

Interoperability is often thought of as little more than a testing activity. Rather, it should be regarded as a thread running through the entire standards development process and not as an isolated issue to be fixed at the end. Of course, testing is an important part of assuring interoperability but it is almost meaningless if the initial requirements gathering and the specification process do not consider interoperability as a fundamental objective."

Although, for the sake of consensus, it may seem attractive to include options and recommendations in a standard, the more they are used, the less likely it becomes that implementations will interoperate. A product that conforms to a standard that includes only mandatory requirements is almost certain to interoperate with other similar products. If it is essential to include an optional requirement within a standard, it should be expressed with a clear indication of the criteria which must be met if the option is to be selected."

The ETSI report [IoT Interop BP] distinguishes between 'Conformance Test Specifications' and 'Interoperability Test Specifications'. It defines relevant documents, comparable to the C-Roads deliverables.

"The structure of an Interoperable Features Statement (IFS) is similar to that of an Interface Conformance Statement (ICS). Its purpose is to identify the functions specified in the base standard(s) which an implementation should support, those which are optional and those which are conditional on the support of other functions. Although not strictly part of the interoperability test suite, the IFS helps to provide a structure to the suite of tests which will subsequently be developed."

Both the ICS and the IFS are good vehicles for the collection of testable requirements from a single base standard or even a coordinated set of specifications from a single standards organization. However, many of today's technologies are standardized as groups of related but nevertheless disjoint specifications from a variety of sources. This is particularly true of IP standardization. Building a coherent set of test specifications from disperse requirements sources can be simplified by gathering the requirements together into a single catalogue.

A Requirements Catalogue lists all implementation requirements from the various sources and organizes them into an appropriate structure. In most cases, creating a tree structure based upon functionality is a valid approach to structuring the requirements. Each node of the tree represents a specified function. Specific requirements are then associated with the relevant function node."

These documents described by ETSI [IoT Interop BP] are similar to what in C-Roads is referred to as Profiles. From the ETSI Interoperability report [IoT Interop BP] it furthermore becomes clear where the scope of ETSI Plugtests ends and thus where the scope of TF5 begins. Based on the description of the relationship between Standards, Validation and Testing as described in the report, the relation to scope of TF5 can be described as given in the figure underneath.

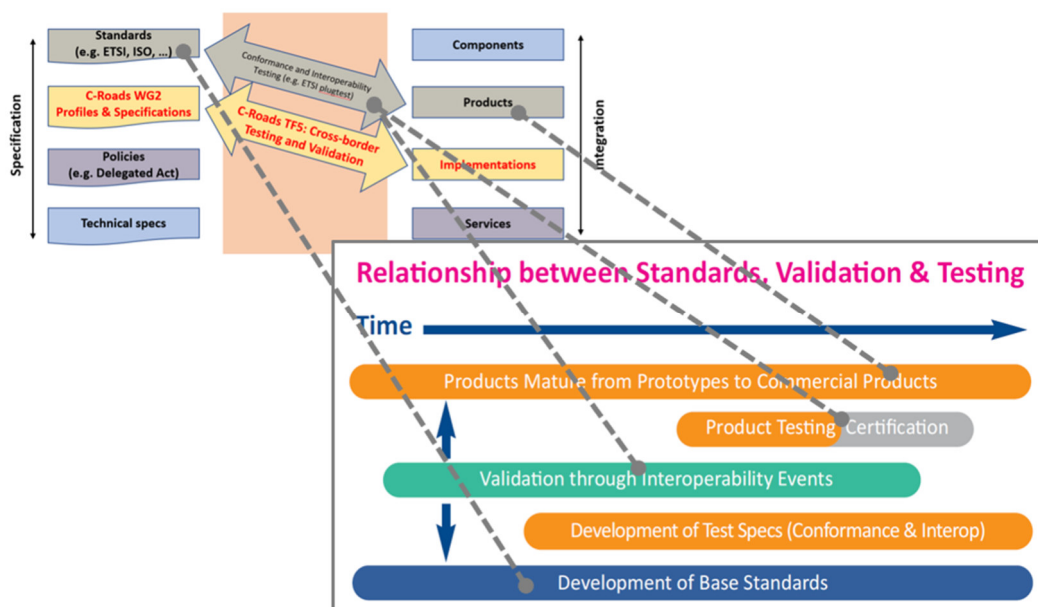


Figure 7: ETSI Standards, Validation & Testing [IoT Interop BP] in relation to scope of C-Roads TF5

2.4. Scope of TF5 for hybrid communications

Hybrid communication covers for transmission of C-ITS messages potentially using multiple communication channels; availability of such communication channels may vary depending on policy, location and requirements set. The Basic Interface (BI) specified in [C-ITS IP Based Interface Profile] relates to the data communication interface used for real time exchange of C-ITS messages in the backend communication and is independent of deployment model that the Member States or C-ITS actors choose to implement communication between backend servers. The BI is based on AMQP V1.0.

The scope of hybrid communication testing is currently restricted to the testing of BI between two C-ITS actors, say X and Y. Actors X and Y can be located in the same country or in different countries.

Both the backend servers of the actors X and Y implement an AMQP client, which takes care of the transmission and receipt of C-ITS messages. In addition to the C-ITS actors, a Broker (B) is used for

routing of the C-ITS messages between the actors (Figure 8). The Broker can be implemented as a single node or can consist of different nodes communicating with each other.



Figure 8: Components in the C-ITS message exchange in hybrid communications

Requirements in [C-ITS IP Based Interface Profile] relate to both the actors X and Y as well as to the broker (B).

Actually, the TF5 scope for hybrid testing is to validate if the communication between the backends of the two C-ITS actors is according to the C-ROADS specifications. This will be extended in the future when the link to the vehicle will be specified.

Moreover, TF5 provides several Test-Cases (TCs) to validate the end-to-end long-range communications of hybrid implementation. Therefore, these TCs are labelled as “Hybrid”, in contrary to the “ITS-G5” ones that were proposed for the short-range communications. If a hosting MS needs to test the “full” hybrid links (i.e., by sending messages about some events simultaneously using the short-range ITS-G5 and the long-range IP-based communications), it needs to execute and validate the ITS-G5 and Hybrid TCs related to these events, separately. In other words, TF5 will not provide “full” hybrid TCs merging the ITS-G5 and Hybrid TCs in order to avoid any confusion, but it recommends that visiting MS will have to validate the reception of these messages using both the ITS-G5 TCs and Hybrid TCs, separately. Then the hosting MS could use these separate TCs’ results to conclude if the messages were received correctly through both channels.

3. Framework

3.1. Introduction

This chapter describes the ‘framework’ for Testing and Validation as perceived by TF5. The framework includes ‘building blocks’ such as test-subjects, requirements-categories, test-types, test-environments, test cases and test-results.

3.2. Test-subject

A test-subject (comparable to ‘test-purpose’ in [IoT Interop BP]) gives the specific aspect within the Profiles that is being tested. TF5 distinguishes the following test-subjects.

- **Security**
- **Facility** (message payload)
 - DENM (e.g. Road Works Warning (RWW))
 - IVIM (e.g. In-Vehicle Signage (IVS))
 - MAPEM/SPATEM (e.g. Green Light Speed Advisory (GLOSA))
- **Network and Transport**
- **Access**

3.3. Requirement-categories

TF5 has divided the requirement in the Profiles into 3 different categories.

- **Category 1 (C1)**. Requirements labelled as C1 are relevant for the local implementation and have to be tested in the country implementing it.
- **Category 2 (C2)**. Requirements labelled as C2 are relevant for cross-border interoperability but can be tested within **the environment** of the local country, operator or manufacturer. They however are a prerequisite for further cross-border testing.
- **Category 3 (C3)**. Requirements labelled as C3 are to be validated by means of actual cross-border tests.

TF5 specifies tests for categories C2 and C3, not for C1. All tests for a service specified by TF5 are mandatory if the MS (Member State) deploys this service.

The hybrid system contains 2 types of actors: the C-ITS actors (X and Y in Figure 8) and the Broker (B in Figure 8). The tests are classified according to the actors required in the tests:

Criteria for identifying the requirement category:

- C1: the requirement can be validated by a single C-ITS actor (X) and the broker (B). In this case the test is performed by e.g. subscribing to the part of the messages transmitted (i.e. X subscribes to a subset of the messages sent by X)
- C2: the requirement can be validated by 2 C-ITS actors from the same country (and a broker).
- C3: the requirement has to be validated by 2 C-ITS actors from two different countries (and the broker).

The broker is a key component of the system. In order to be able to perform the testing, a broker has to be made available. Other brokers will have to be tested against the specifications.

3.4. Test-type

TF5 distinguishes the following five types of tests. The test cases specified by TF5 will be among the test-types “Lab-test” and “Road-tests”.

- **Lab-test.** The laboratory testing is the first step to validate the ability of a communication unit or system to operate the basic functionalities to implement Day 1 C-ITS services and use-cases in laboratory environment where there are no risks of influencing the road safety and security. The goal of this testing is to tune the properties before implementing the C-ITS system in real environment. During this procedure the I2V interaction between R-ITS-Ss and V-ITS-Ss from different origin will be tested.
- **Controlled test.** These tests are performed outside but in a controlled environment. ITS-G5 coverage and messages (DENM, IVIM, SPATEM, MAPEM, CAM, ...) need to be provided in the test area. These tests shall allow participants to drive at low speeds for a short distance within the coverage area of an R-ITS-S in order to test the correctness of received information at their V-ITS-S in an open-air ‘laboratory’ environment. This environment shall allow actual driving in short loops with the possibility to directly correct flaws if required.
- **Road-tests.** These tests are performed on actual roads, in real-life traffic. ITS-G5 coverage from multiple R-ITS-Ss spaced at relevant distances and relevant message sets (DENM, IVIM, SPATEM, MAPEM, CAM, ...) representing realistic scenarios need to be provided on the road. Specific safety instructions will be required. These tests shall allow participants to test their equipment in a real live environment. Scenarios may be virtual or live. Virtual scenarios are predefined but imaginary traffic situations. These scenarios may be supported by a photo-script depicting the imaginary traffic situations. Live scenarios are actual real-life traffic situations, e.g. road works and/or traffic jams.
- **Operational tests.** These tests are, like road-tests, performed in real-life traffic situations but are stretching a longer period. Operational tests shall focus on functioning and performance of the systems over weeks or months instead of hours or days. Operational tests will in most cases be performed by technical experts or at least skilled users.
- **Pilots.** Pilots are tests over longer periods involving real end-users (road operators). The participants, although chosen specifically for the pilots, shall be representative for actual future end-users.

For hybrid systems, as the main focus is on the backend communication, all the tests provided until now can be performed as **Lab tests** and as **Pilots**. TF5 will provide on-road tests to validate the whole end-to-end hybrid communication link.

3.5. Test-environment

- **Single country tests:** Performed within the context of a single country.
- **Cross-border tests:** Bilateral cross-border testing involving two or more countries, operators or manufacturers.

The “Test-environment” parameter may also include further details such as number of lanes, etc. if required.

For the Tests hybrid, the “Test-environment” may include 3 actors, as described in section 3.3.

3.6. Test case

The test case provides a description of the individual test. The ETSI Interoperability report [IoT Interop BP] gives the following advice with respect to test-descriptions.

“A test-description should include as a minimum:

- *a unique test description identifier*
- *a concise summary of the test which should reflect the purpose of the test and enable readers to easily distinguish this test from any other test in the document*
- *a list of references to the base specification section(s), use case(s), requirement(s), TP(s) which are either used in the test or define the functionality being tested*

- a list of features and capabilities which are required to be supported by the System Under Test (SUT) in order to execute this test (e.g. if this list contains an optional feature to be supported, then the test is optional)
- a list of all required equipment for testing and possibly also including a (reference to) an illustration (or a reference to it) of a test architecture or test configuration
- a list of test specific pre-conditions that need to be met before the test sequence can commence an ordered list of manual or automated operations and observations.”

TF5 has defined a template for the description of test cases. Below is an example of the template for testing the service “Road Works Warning”.

	TF5 Test-case description	
Service	Road Works Warning (RWW)	
Use case	Lane Closure (and other restrictions) RWW-LC	
TC ID	TC_CROADS_RWW-LC_ITSG5_DENM_LaneClosure_26_R1.8.0	
Test case name	DENM "Road Works" check the availability of DENM lane closure sent through ITS-G5	
Requirements Specifications	C-ITS Infrastructure Functions and Specifications Version 1.6, section 3.2.1.2, table 6 Common C-ITS Service Definitions Version 1.6 section 3.2.1	
Test objective (Short description)	To check the availability of the transmitted DENM	
Test environment	On-Road	
Test setup	V-ITS-S from country A enabled to receive DENM and R-ITS-S from country B Please note that the HMI is used only for testing purposes and is out of scope	
Initial Conditions		
R-ITS-S is launched and transmits a DENM with a Cause Code CC and SubcauseCode SubCC. V-ITS-S is launched and moving towards the R-ITS-S		
Test scenario		
1. R-ITS-S is sending DENM with CC and SubCC 3. V-ITS-S is travelling towards R-ITS-S		
Test variables		
CC =3,15,26,95 SubCC = 0,1,2,3,4,5,6,8		
Expected behaviour		
1. V-ITS-S approaches R-ITS-S 2. V-ITS-S receives the DENM sent from R-ITS-S 3. V-ITS-S considers the transmitted event as relevant		
Minimum number of repetitions	3	
Test's comments	The test is to be repeated with available cc and SubCC. Further tests could be carried out by changing the position of R-ITS-S.	
Verification Points (VP)		
VP#	Description	Threshold
1	Does the received DENM contain CC and subCC values as expected?	Checked
Test Validation Conditions	The verification point 1 has passed in all the repetitions	

Figure 9: TF5 Test case description for testing services defined by TF2 (example)

- **Service:** The service as defined by TF2 [C-Roads SUD] which is tested.
- **Use case:** The use case as defined by TF2 [C-Roads SUD] which is tested.
- **TC ID:** The test case ID, defined as: TC_CROADS_USECASE-ID_COMMUNICATION-MODE_MESSAGE-TYPE_TESTED-DATA-ELEMENT_TESTID_TESTVERSION.
 - For example:
 - TC_CROADS_RWW-LC_ITSG5_DENM_LaneClosure_26_R1.7.0.
 - In specific:
 - USECASE-ID: Abbreviation of applicable use case as defined by TF2 [C-Roads SUD]
 - COMMUNICATION-MODE: either ITSG5 or HYBRID
 - MESSAGE-TYPE: either DENM, IVIM, SPaTEM or MAPeM
 - TESTED-DATA-ELEMENT: Data element from TF3 [C-Roads MP]

- *TESTID*: a unique ID to take multiple test cases on the same TESTED-DATA-ELEMENT into account
 - *TESTVERSION*: the version of the TC formatted as MAJOR.MINOR.PATCH.
- **Test case name**: Short descriptive name.
- **Requirements Specifications**: Document reference of the specific requirement, defined as: C-Roads specification XXXX Version X.X paragraph X of Section X.
- **Test-objective** (Short description): Short description of the test.
- **Test-environment**: Lab test or Road test
- **Test-setup**: List of equipment or software needed for the test, for example: Sniffer, vehicle equipped with an ITS station, mobile R-ITS-S, etc.
- **Initial Conditions**: The basic settings of the equipment and/or the pre-request tests which are assumed to have been performed in advance. For example:
 - *R-ITS-S is launched and transmits a DENM with a Cause Code CC and SubcauseCode SubCC.*
 - *V-ITS-S is launched and moving towards the R-ITS-S*
- **Test-scenario**: Description of the step-by-step scenario. For example:
 - *R-ITS-S on the trailer/vehicle is switched on*
 - *R-ITS-S is sending DENM with CC and SubCC*
 - *V-ITS-S is travelling towards R-ITS-S*
 - The information about lane position provided by TCC
- **Test-variables**: The values of the variables used in the scenarios. For example:
 - CC = 3
 - SubCC = 0;4
 - Lane position 0,1,2,3,4
- **Expected behaviour**: The expected outcome formulated positively. For example:
 - *V-ITS-S receives the DENM sent from R-ITS-S*
 - *The event message contains the transmitted CC, SubCC values and lane position*
- **Minimum number of repetitions**: The number of test repetitions needed in order to validate the requirement. Three (3) is the recommended number of repetitions for testing services, whereas test cases for security and hybrid communication might require only one (1) repetition.
- **Test-comments**: Add comments if needed. For example:
 - *The test is to be repeated with different SubCC and lane position*
- **Verification Points (VP)**: The list of elements to be checked in order to validate the test. The points of verification are to be formulated as questions.
- **Test Validation Conditions**: The list of mandatory VPs to be validated against the threshold in order for the test to be successful.

Test-Case for TF1 Security:

Following is an example of a test-case for security based on requirements defined by TF1 [C-ITS Security Requirements and Specifications].


	TF5 Test-case description template	
Service	To be filled...	
Use case	To be filled...	
TC ID	TC_CROADS_GENERIC_SECURITY_ECTL_Update	
Test case name	ECTL present and updated	
Requirements Specifications	Draft Report on European Security Mechanism V1.7 / B1.7. Verification of message signature / B1.7.1. Pre-Conditions	
Test objective (Short description)	The ECTL is provided to the ITS-S during the initialization phase and is updated periodically (if possible even during operation)	
Test environment	On-Lab	
Test setup	Tested ITS-S with an ECTL about to be expired in few minutes	
Initial Conditions		
The ITS-S is launched		
Test scenario		
1. ITS-S verifies the presence of a valid ECTL 2. ECTL expires 3. ITS-S downloads a new ECTL		
Test variables		
Expected behaviour		
1. Valid ECTL is downloaded and used by the ITS-S		
Minimum number of repetitions	1	
Test's comments		
Verification Points (VP)		
VP#	Description	Threshold
1	Is a valid ECTL provided in the ITS-S?	Checked
2	Is a new valid ECTL was downloaded after the expiration of the current ECTL?	Checked
Test Validation Conditions	The verification points 1 and 2 have passed	

Figure 10: TF5 Test case description for testing security defined by TF1 (example)

Test-Case for TF4 Hybrid Communication:

Following is an example of a test-case for hybrid communication based on requirements defined by TF4 [C-ITS IP Based Interface Profile].

<div>C-ROADS</div>		TF5 Test-case description template		
Service				
Use case				
TC ID		TC_CROADS_GENERIC_Hybrid_DENM_Routing		
Test case name		Generic DENM using Hybrid for Routing verification		
Requirements Specifications		C-Roads specification Hybrid (BI) Version 1.6: HYB_025, additionally: hyb_026, HYB_027, hyb_043, hyb_049		
Test objective (Short description)		The DENM is routed correctly and received by the service operator (and repeated)		
Test environment		Lab test		
Test setup		Actor SP1 from country 1, Broker, Actor SP2 from country 2		
Initial Conditions				
1. Selecting the use-case to be tested (CC and SubCC). The message is repeated (according to the specifications) every 9 minutes				
2. SP1, Broker and SP2 are connected and TLS certificates in place				
3. SP1 subscribes to all events				
Test scenario				
1. SP2 publishes DENM over BI interface. The message is signed at geonet level prior to transmission. The DENM is repeated every 9 minutes				
2. Broker routes the message to SP1				
3. SP1 receives DENM				
Test variables				
Mandatory AMQP Application Properties Fields: publisher-ID: SP2code; orig-country: country 2; protocolVersion: DENM:1.2.2; messageType: DENM quadTree: Q1234567890abcdefg CauseCode = XX SubCauseCode = XX				
Expected behaviour				
1. The message is received and validated in the backend of SP1 (outside scope: 2. The message is sent to the vehicle and appears on the vehicle HMI)				
Minimum number of repetitions		3		
Test's comments		New test run correspond to the same message repeated after 9 minutes.		
Verification Points (VP)				
VP#		Description		Threshold
1		The message is routed to the correct queue		Checked
2		The message is received at SP1		Checked
3		All mandatory AMQP Application Properties fields are present		Checked
4		The content of the mandatory AMQP Application Properties fields corresponds to the specific		Checked
5		The message geonet certificate is validated at SP1		Checked
6		The content of the received message is identical to the transmitted		Checked
Test Validation Conditions		The verification points 1,2,3,4,5,6 have passed in all repetitions		

Figure 11: TF5 Test case description for testing hybrid communication defined by TF4 (example)

3.7. Test-result

Each test should provide a clear, preferably a Pass or Fail or Inconclusive, test-result. In case of Fail or Inconclusive the tester has to provide a comment. The document ETSI Interoperability report [IoT Interop BP] gives the following advice.

“At the end of each test case (and, where necessary, interspersed with the test steps) it is important to specify the criterion for assigning a verdict to the test case. This is probably best expressed as a question.

Verdict criteria need to be specified as clearly and unambiguously as test steps and without restrictions. If a criterion is expressed as a question, it should be constructed in such a way that “Yes”

and "No" are the only possible answers and it should be clear which result represents a "Pass" verdict and which represents a "Fail".

Although it is clear that a "Pass" verdict will always mean that, for a specific test, the connected devices interoperate correctly, it may not be the case that a "Fail" verdict implies that they do not. The interconnecting network equipment plays an essential role in almost all interoperability tests but is not usually included in the equipment being tested. A "Fail" verdict may be caused by a fault or unexpected behaviour in the network. Thus, each "Fail" verdict should be investigated thoroughly, possibly using monitoring equipment to determine its root cause before either validating the verdict as a true failure (if the root cause is within the tested devices) or retesting."

TF5 has defined a template for reporting the test result as follows.


 C-ROADS	TF5 Test-run						
Service	In Vehicle Signage (IVS)						
Use case	Shock Wave Damping (IVS-SWD)						
TC ID	TC_CROADS_IVS-SWD_Hybrid_IVIM_ISO14823Code_47_R1.7.0						
Test case name	Testing ISO14823 Code in IVS-SWD using Hybrid						
Test site/location							
Testing country							
Test case date							
Test case time							
Verification Points (VP) #	Run 1	Run 2	Run 3	Comments			
Security on/off							
VP 1							
VP 2							
VP 3							
Verdict							
Test Comments							

Figure 12: TF5 Test-run (example)

- **Service:** same as in test case template.
- **Use case:** same as in test case template.
- **TC ID:** same as in test case template.
- **Test case name:** same as in test case template.
- **Test site/location:** location where the test has been carried out. Only valid for on road testing.
- **Testing Country:** involved country(ies) (within C-Roads, this implies also the pilot site and the tested equipment, based on a shared database for all use cases; any special configurations should be explicitly listed here). For example:
 - for Single country test: Country A (special equipment)
 - for Cross-border test: Country A (special equipment) and Country B (special equipment).
- **Test case date:** The date, test was carried out
- **Test case time:** Time of the test
- **Security on/off:** Indicates whether the test was carried out with or without security turned on.
- **Verdict:** the overall verdict of the test. There are 3 verdicts possible:
 - Pass: the Test Validation Conditions of the test case are fulfilled
 - Fail: the Test Validation Conditions of the test case are not fulfilled for a certain reason
 - Inconclusive: the Test Validation Conditions of the test case are not fulfilled for an unknown reason
- **Test Comments:** Add comments if needed.

3.8 Common template for reporting

It is mandatory for each hosting MS to use the common template for reporting of all C-Roads cross-border testing results (C-ITS Cross-Border Testing Report Template, Version 0.6) that was already validated during the December 2020 SCOM.

4. Process

4.1. Introduction

The Cross-border Testing and Validation process is divided into two main parts:

1. The detailed analysis of the requirements within the Profiles to produce test-cases for each of requirements
2. The actual tests are to be performed and executed in the proper order to ensure interoperability, TF5 defines 3 main steps to be performed:

- 2.1. On-lab tests: these tests include ETSI conformance tests and tests that belong to C1 and C2 categories extracted from C-Roads Functions & Specifications [C-Roads MP] and C-Roads Roadside System Profile [C-Roads RSP]. They are let to the responsibility of the MS to be validated. No tests will be provided by TF5 except the DENM tests that are linked to C2 category.
- 2.2. PCAP (Packet Capture) exchanging: TF5 provided a complete specification for PCAP exchanging specification. A separate deliverable is provided to specify the procedure of PCAP exchanging between MS. The exchange of PCAP files is linked to tests of category C3 as a prior step for on-road testing.
- 2.3. On-road tests: these tests are linked to C3 category. They will be provided by TF5 for all the use-cases included in the “C-Roads Common C-ITS Service and Use Case Definitions” document [C-Roads SUD]. TF5 will also provide a common log specification.

To facilitate cross-border tests, it is important that detailed information about the cross-border environment is available. This information should contain a clear access point, the locations for specific test subjects and the test equipment.

For hybrid, the process involves:

1. The detailed analysis of the requirements within the specification for interoperability of backend hybrid C-ITS communication [C-ITS IP Based Interface Profile] to produce test cases for each requirement.
2. The actual tests are to be performed and executed in the proper order. To ensure interoperability.
 - On-lab tests: the following tests are included:
 - C1 tests: validation of the basic functioning of the backend. Tests are performed by connecting to a broker (e.g. reference implementation of a broker), and by subscribing to queues related to the message transmitted.
 - C2 tests: exchange of messages with another C-ITS actor, which can be from the same country.
 - C3 tests: exchange of messages with a C-ITS actor from another country.
3. Logging
 - For logging the following logs should be produced during the tests:
 - LOG1: log of the C-ITS messages to be transmitted
 - LOG2: log of the data transmitted over AMQP
 - LOG3: log of the data in the receiving queue
 - LOG4: log of the received messages after validation

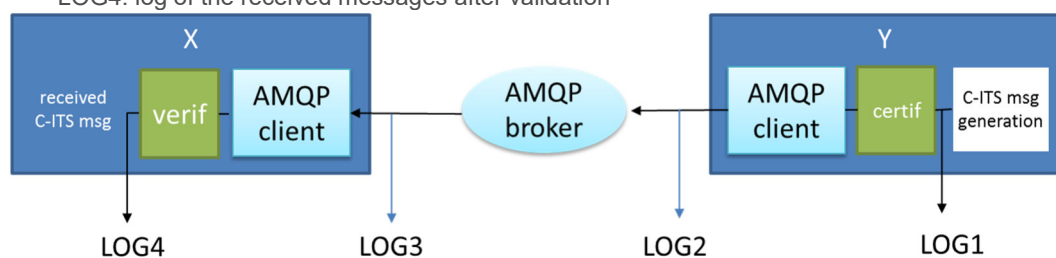


Figure 13: TF5 Test-run (example)

4.2. Analysis and description

The requirements contained in the C-Roads profile and specification documents “C-Roads Common C-ITS Service and Use Case Definitions” [C-Roads SUD], C-Roads Functions & Specifications [C-Roads MP], “C-Roads Roadside System Profile” [C-Roads RSP] provided by TF2 and TF3 are analysed with respect to their relevance and impact on interoperability. Each requirement is carefully investigated and classified.

4.2.1 Analysis and description of TF3 deliverables

The following methodology's steps are executed¹:

1. The input documents are discussed during regular TF5 (web-)meetings.
2. The content (e.g. the different Data Elements) is investigated according to the following philosophy:
 - Not mandatory in the profile:
 - Not critical for interoperability.
 - Verified locally by Single tests.
 - Mandatory in the profile:
 - Mandatory in the standard without requirements:
 - No tests provided, the standard is enough (conformance tests are requirements).
 - Mandatory in the standard with additional requirements:
 - TF5 will provide tests.
 - Verify the requirements (Single tests in general to be validated before Cross-border tests).
 - Optional in the standard without requirements:
 - TF5 will provide tests.
 - Check availability (Single tests in general to be validated before Cross-border tests).
 - Optional in the standard with additional requirements:
 - TF5 will provide tests.
 - Check availability and additional requirements (Single tests in general to be validated before Cross-border tests).
3. The requirements are classified based on the previous analysis as follows:
 - Category 1: Not critical for interoperability.
 - TF5 will not provide tests, these requirements will have to be validated locally.
 - Category 2: Important for interoperability but could be tested locally.
 - TF5 will provide tests, these requirements will have to be validated locally before cross-border testing.
 - Category 3: Critical for interoperability and have to be tested bilaterally.
 - TF5 will provide tests, these requirements will have to be tested on field with two countries.
4. The resulting classifications are sent to TF3 for feedback.
5. The classifications are updated based on the TF3 feedback.
6. The use-cases to be tested are selected (risk-based):
 - There are (too) many services and use cases and providing tests and executing them requires a lot of time.
 - Therefore, TF5 selects the most deployed use-case for each service:
 - Road Works Warning - Lane Closure (RWW-LC); causeCode 3 and subCauseCode 0 or 4.
 - Hazardous Location Notification - Stationary vehicle (HLN-SV); causeCode 94 and subCauseCode 0 or 2.
7. The test cases for the selected use-cases are written.

The table in the Appendix A.1 gives an example.

4.2.2 Analysis and description of TF2 deliverable

The following methodology steps are executed:

1. The input documents are discussed during regular TF5 (web-)meetings.
2. Few test generic subjects are extracted for the different use-cases that are based on the same type of messages, namely DENM, IVIM, SPATEM, MAPEM, SREM and SSEM. Some examples of these subjects are: Event Position, Timing, Update/Cancel, etc.

¹ Note that this procedure applies to DENM for the moment. It will not be performed to IVIM, MAPEM and SPATEM. This is let to the responsibility of the MS.

3. The different services and the use-cases are investigated to extract some specific subject to be tested that are related only to a specific use-case.
4. The resulting classifications are sent to TF2 for feedback.
5. The classifications are updated based on the TF2 feedback. In some cases, also a joint TF2, TF3 and TF5 expert discussion was used at this process level to identify the correct technical specification for testing and validation of the functional requirements (i.e. for SREM and SSEM based use cases).
6. The test cases are written for all the specified use-cases.

The table in the Appendix A.2 gives an example.

4.2.3 Analysis and description of TF4 deliverable (BI interface)

The following methodology steps are executed:

1. The input documents are discussed during regular TF5 (web-)meetings.
2. The content is investigated according to the following philosophy:
 - a. Not mandatory: verified locally by Single tests
 - b. Mandatory requirements:
 - i. assessment of the amount of partners needed for performing the tests:
 1. Can the test be performed by a single operator and by subscribing to the own input?
 2. Is the requirement critical for guaranteeing interoperability?
 3. Can the requirement be validated with another operator of the same country?
3. For those tests, requiring operators from different countries, test cases are specified addressing the data fields which are critical.
4. The resulting classifications are sent to TF4 for feedback.
5. The classifications are updated based on the TF4 feedback.
6. The test cases are written for all the specified use-cases.

4.2.4 Analysis and description of TF1 deliverable (Security)

The following methodology steps are executed:

1. The input documents are discussed during regular TF5 (web-)meetings.
2. The content is investigated according to the following philosophy:
 - a. Not mandatory: verified locally by Single tests (e.g. Stations are able to request valid AT to a PKI, sign messages and produce a C or SP compliance report).
 - b. Mandatory requirements:
 - ii. assessment of the amount of partners needed for performing the tests:
 1. Can the test be performed by a single operator and by subscribing to the own input?
 2. Is the requirement critical for guaranteeing interoperability?
 3. Can the requirement be validated with another operator of the same country?

3. For those tests, requiring operators from different countries, test cases are specified addressing the data fields which are critical.
4. The resulting classifications are sent to TF1 for feedback.
5. The classifications are updated based on the TF1 feedback.
6. The test cases are written for all the specified use-cases.

The table in the Appendix A.3 gives an example.

The design of the test cases is based on the following considerations:

- Some requirements are easier to test in a “lab” mode (stations operators in the same place). For instance, tests of the signature verification in this mode are more efficient than in an “on road” mode.
- Tests of service specific permissions are use case specific whereas tests of security initialisation and verification of message signature are independent of use cases.
- Validation (especially for TF1 report requirements) requires negative testing scenarios (i.e. error cases). This requires several test sets with specific security elements, including (non-exhaustive):
 - Invalid TLM certificate or ECTL
 - Revoked ACs
 - Expired certificates
 - Untrusted ACs
 - ATs without proper permissions

Before participating to Cross-testing security, each MS is asked to validate its equipments’ security implementation. For that, the security pre-requisites are validating the following security Test cases:

- C-Roads_TF5_Test-cases_DENM_Security_CertifFormat_1
- C-Roads_TF5_Test-cases_DENM_Security_CertifValidity_2
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_IVI_R-ITS-S (RSU)_3
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_IVI_R-ITS-S (VRO)_3
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_RLT_R-ITS-S (RSU)_3
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_RLT_R-ITS-S (VRO)_3
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_TLC_R-ITS-S (RSU)_3
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_TLC_R-ITS-S (VRO)_3
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_TLM_R-ITS-S (RSU)_3
- TC-CROADS_GENERIC_SECURITY_HOME_AT-Permission_TLM_R-ITS-S (VRO)_3
- TC_CROADS_GENERIC_SECURITY_HOME_AT-Permission_CAM_RSU_3
- TC_CROADS_GENERIC_SECURITY_HOME_AT-Permission_CAM_VRO_3
- TC_CROADS_GENERIC_SECURITY_HOME_AT-Permission_DENM_RSU_3
- TC_CROADS_GENERIC_SECURITY_HOME_AT-Permission_DENM_VRO_3
- TC_CROADS_GENERIC_SECURITY_ECTL_Update_4
- TC_CROADS_GENERIC_SECURITY_RCA-CTL_Available_4
- TC_CROADS_GENERIC_SECURITY_HOME_RCA_Verification_4
- TC_CROADS_GENERIC_SECURITY_CRL_Verification_4
- TC_CROADS_GENERIC_SECURITY_CTL_Verification_4
- TC_CROADS_GENERIC_SECURITY_TLM_ECTL_4
- TC_CROADS_GENERIC_SECURITY_TLM_CERTIFICATE_VALIDATION_4
- C-Roads_TF5_Test-cases_SECURITY_AA_NOMINAL_5
- C-Roads_TF5_Test-cases_SECURITY_AT_NOMINAL_5
- C-Roads_TF5_Test-cases_SECURITY_RCA_NOMINAL_5
- C-Roads_TF5_Test-cases_SECURITY_SIGNATURE_NOMINAL_5

4.3. Test execution

The organization of actual tests is not within the scope of TF5. TF5 will however specify minimum common logs for road-tests, operational tests and pilots. This section provides a guideline for the process of executing these tests.

Tests will be based on an overall test-plan describing the process of testing the individual test cases. Not all tests are mandatory, only those elements/services/uses cases which are relevant for the implementation on each pilot site need to be tested. If the test case contains descriptions of elements not defined as “mandatory” by the C-Roads specifications used for the pilot phase, the execution of these parts is not a requirement. The test case (or the specific part) will be considered “not applicable” to the specific pilot that does not support the optional features described in the test cases.

Firstly, all underlying tests (i.e. C1 and C2) shall be performed within the context of the individual country. After successful conclusion of these tests the subsequent C3 tests will be performed in a cross-border environment. In this step the I2V interaction between R-ITS-Ss and V-ITS-Ss from different origins will be tested.

For the execution of the C3 tests (on-road bilateral tests), each MS has to select a Pilot Site to test each implemented UC (use case). A MS may have only one or more than one Pilot Sites. However, it must well identify the Services / Use-cases that can be tested within each Pilot Site in the corresponding Fact Sheets. It is noticed also that, for each UC, a MS must select an equipment (RSU or Vro) as a reference for testing, when hosting Cross-Tests and when testing in another MS. The equipments, used as reference, must be specified in the “**Testing Country**” field of the test result sheet presented in the section 3.7.

Each of these steps will start with the generic requirements, followed by the more specific requirements. For TF3 specification, tests for generic requirements will be performed only once for the representative service or use case, unless it is – based on risk-assessment – required to perform it again for a specific situation (e.g. the eventPosition in case of moving RWW as compared to static RWW). For TF2 specification, tests are performed for all the use-cases.

Each step in the test-process will have its own results. At the end, the final test-results will have to be evaluated and a final report will have to be prepared.

4.4. On-Road Data Logging

This section details the needs in terms of data logging from the hosting and visiting MS.

4.4.1 ITS-G5 data logging

During the on-road ITS-G5 testing, each equipment, which is used in the tests (RSU, Vro and OBU) needs to store all the sent and received packets using PCAP format. They will be used offline for debugging if some events are not well received or interpreted. If the need will appear to specify more advanced logs, a more detailed specification will be provided by TF5.

4.4.2 Hybrid data logging

For logging of the messages transmitted between the backends using the IP-based protocols, logging functionalities provided by the AMQP client providers are planned to be used. As different providers may provide different ways to log messages, the issue will be further agreed between the developers in the Developers Forum, which is set up in the framework of C-ROADS TF4.

4.5. Test results collecting process

During each cycle of tests, each hosting MS needs to collect all the logs and the test results sheets from the different visiting MS. These sheets will support the hosting MS to fill the C-ITS Cross-Border Testing Report. Moreover, the hosting MS could use any other tool in order to measure other performance metrics that could enhance the quality of the report such as the latency, packet delivery ratio, etc.

All these single MS reports will be merged in a European interoperability report that will allow to validate an important C-Roads platform milestone.

4.6. Virtual testing session organisation

The exchange of sent and received C-ITS messages as PCAPs (packet capture files), which can - without any modification - be tested by all partners is a proper way to replace physical tests and drives.

Through the provision of detailed PCAPs, e.g. via a common platform for all partners, it can be assured that all participants receive the same data in the same format with the same quality.

The tests of these PCAPs are conducted in the same way – except that the messages are not received during physical drives by the individual testers, but are received, recorded and then shared virtually by the local pilot site team. For more details about the specifications and the organisation of the virtual testing session, please refer to the chapter 3 of the deliverable “TF5_C-ITS_Cross-Border_Testing-PCAP_Exchange_Specification_R2.0.1”.

Appendix

A.1. Example of TF3 requirements analysis

Table 4: Analysis of requirements of TF3 deliverable (example)

Type of Message	Service	Requirement #	Document Reference	Requirement or Data Element	To be tested	Type of test C1/C2/C3	What?	Actions	Comments
DENM	DENM in general	1	Section 2.1	S.8 GHz DSRC / 5.9 GHz C-ITS Coexistence System FLS	No	C1		No action	No important for interoperability
		2	Table 3 in section 3.2.1.1	actionID	Yes	C2	Availability	Specify tests for all different types of DENM	
		3		detectionTime	Yes	C2	Availability	Specify tests for all different types of DENM	
		4		referenceTime	Yes	C2	Availability and value	Specify tests for all different types of DENM	the synchronization is important (perhaps C3)
		5		termination	No	C1	Not mandatory	No action	No important for interoperability
		6		eventPosition	Yes	C2	Availability and value	Specify tests for all different types of DENM	set a position by the tester and then verify the generated message
		7		relevancDistance	No	C1	Not mandatory	No action	No important for interoperability
		8		relevancDistanceDirection	Yes	C2	Availability and value = (1)	Specify tests for all different types of DENM	
		9		validityDuration	Yes	C2	Availability	Specify tests for all different types of DENM	
		10		TransmissionInterval	No	C1	Not mandatory	No action	No important for interoperability
		11		stationType	Yes	C2	Availability and value = (9, 10, 15)	Specify tests for all different types of DENM	
		12		informationQuality	Yes	C2	Availability and value = (0, 7, 4, 6, 7)	Specify tests for all different types of DENM	if informationQuality = 0 -> message rejected
		13		eventType	Yes	C2	Availability	Specify tests for all different types of DENM	
		14		relatedCause	No	C1	Not mandatory	No action	No important for interoperability
		15		eventHistory	Yes	C2	Availability	Specify tests for all different types of DENM	
		16		eventSpeed	No	C1	Not mandatory	No action	No important for interoperability
		17		eventPositionHeading	Yes	C2	Availability	Specify tests for all different types of DENM	
		18		traces	Yes	C2	Availability	Specify tests for all different types of DENM	
		19		Alcatel Container	No	C1	Not mandatory	No action	No important for interoperability
	DENM for RWW	20	Table 4 in section 3.2.1.1	Service parameters for DENM in general	No	C1	Not important for interoperability for TF3	Contact TF3	
		21	Table 6 in section 3.2.1.2	eventPosition	No	C2	Already tested for DENM in general	No action	
		22		relevancDistance	No	C1	Not mandatory	No action	No important for interoperability
		23		causeCode	Yes	C2	Availability and value = (3)	Specify tests only for RWW	
				subCauseCode	Yes	C2	Availability and value = (0, 1, 2, 3, 4, 5)	Specify tests only for RWW	0 is used for unknown Alert planned road works – mobile: 3 Closure of part of a lane, whole lane or several lanes: 0,1,2,4,5 Alert planned closure of road or a carriageway: 3,4
		24		lanePosition	Yes	C2	Availability	Specify tests only for RWW	
		25		closedLanes	Yes	C2	Availability	Specify tests only for RWW	Choosing some closed lanes and verify the generated message
		26		speedLimit	No	C1	Not mandatory	No action	No important for interoperability
		27		recommendedPath	No	C1	Not mandatory	No action	No important for interoperability
		28		startingPointSpeedLimit	No	C1	Not mandatory	No action	No important for interoperability
		29		trafficFlowRule	No	C1	Not mandatory	No action	No important for interoperability
		30		reference DENMs	No	C1	Not mandatory	No action	No important for interoperability
		31	Table 7 in section 3.2.1.2	Service parameters for RWW	No	C1	Not important for interoperability for TF3	Contact TF3	
		32	Table 8 in section 3.2.1.3	relevancDistance	No	C1	Not mandatory	No action	No important for interoperability
	DENM for HLN	33	Table 9 in section 3.2.1.2	Service parameters for HLN	No	C1	Not important for interoperability for TF3	Contact TF3	Test the reception mandatory, but the sending have to be discussed
IVIM	IVIM in general	34	Table 10 in section 3.2.2.1	serviceProviderId	Yes	C2	Availability and value is correct and unique	Specify tests for all different types of IVIM	
		35	Table 10 in section 3.2.2.1	identificationNumber	Yes	C2	Availability and value is the same for repetition	Specify tests for all different types of IVIM	
		36	Table 10 in section 3.2.2.1	timestamp	Yes	C2	Availability and value	Specify tests for all different types of IVIM	
		37	Table 10 in section 3.2.2.1	validFrom	No	C1	Not mandatory	No action	No important for interoperability
		38	Table 10 in section 3.2.2.1	validTo	Yes	C2	Availability and value time in the future	Specify tests for all different types of IVIM	for TF3 "An update shall be sent before the message times out." means an update and not a new message, but have not to be tested
		39	Table 10 in section 3.2.2.1	connectedToStructures	No	C1	Not mandatory	No action	No important for interoperability
		40	Table 10 in section 3.2.2.1	status	Yes	C2	Availability and value = (0, 1, 2, 3)	Specify tests for all different types of IVIM	
		41	Table 10 in section 3.2.2.1	referencePosition	Yes	C2	Availability and value	Specify tests for all different types of IVIM	set a position by the tester and then verify the generated message
		42	Table 10 in section 3.2.2.1	referencePositionTime	No	C1	Not mandatory	No action	No important for interoperability
		43	Table 10 in section 3.2.2.1	referencePositionHeading	No	C1	Not mandatory	No action	No important for interoperability
		44	Table 10 in section 3.2.2.1	referencePositionSpeed	No	C1	Not mandatory	No action	No important for interoperability

A.2. Example of TF2 requirements analysis

Table 5: Analysis of requirements of TF2 deliverable (example)

Service	Use Cases	Type of Message	Document Reference	Requirement #	Requirement or Data Element	Requirement Dependence Level [Service, UC, Scenario]	Testsubject	Type of test C1/C2/C3	To be tested	Comments
Hazardous Locations Notification (HLN) and Road Works Warning (RWW)	Generic		Common C-ITS Service Definitions Version 1.3 / Section 2 and Section 3	1	Position of Event	Service Generic	The event is allocated on the correct position	C3	No	Already written together
				2	Traces	Service Generic	The traces lead to the event	C3	Yes	
				3	Timing	Service Generic	The DENM is received in advance to the event	C3	Yes	
				4	Update/ Cancel	Service Generic	The test subject is still perceivable	C3	Yes	
	Accident Zone (HLN-AZ)		Common C-ITS Service Definitions Version 1.3 / Section 2.2.1	5	causeCode & subCauseCode	Use-case Specific	For this use-case, causeCode is 2 (accident) and subCauseCode is between 0 and 7 except 6 (vehicle; which is implicit for an accident).	C3	Yes	
	Traffic Jam Ahead (HLN-TJA)		Common C-ITS Service Definitions Version 1.3 / Section 2.2.2	6	causeCode & subCauseCode	Use-case Specific	CauseCode shall be set to 27 (dangerous end of queue) and subCauseCode shall be set to 0	C3	Yes	
	Stationary vehicle (HLN-SV)		-ITS Service Definitions Version 1.3 / Section 2.2.3	7	I2V broadcast, (with V2I combined with V2V broadcast as additional input source) - same requirement as "Use Case Scenario"	Use-case Specific		C3	No	
				8	Each lane (including shoulder) in the direction of travel (upstream) should be received the SV warning.	Use-case Specific		C3	Yes	
				9	If the lane is recognized by detection of camera, road user should also be informed of the lane information of the stationary vehicle.	Use-case Specific		C3	No	
				10	There may be more stationary vehicles in the same location. All SV warnings shall be received.	Use-case Specific		C3	No	Not included in the specification
				11	Stationary vehicle can also be special vehicle(s), like emergency vehicle with shined light bar. In this case, the status of the emergency lights/StationType etc. shall be checked.	Use-case Specific		C3	No	Not included in the specification
				12	For generating the vehicle based warning in the same way for a fast detection of slow or stationary vehicles at the Roadside a common implementation of the triggering conditions in the vehicles is requested.	Use-case Specific		C3	No	
				13	The corresponding CauseCode and SubCauseCode for different reasons of the stationary vehicle shall be correct sent.	Use-case Specific		C3	Yes	
					For this use-case, causeCode is 94 (stationary vehicle) and subCauseCode is 0 (unavailable) or 2 (breakdown vehicle).					

A.3. Example of TF1 requirements analysis

Table 6: Analysis of requirements of Security TF1 deliverable (example)

	test cases	
Formats of certificates shall be compliant with section B1.1 of '0190827_TF1_Security_report_v1.7 [8].	see B 1.1	1 RSU sends out message, certificate needs to be verified
Validity times of certificates shall be compliant with section B1.2 of '0190827_TF1_Security_report_v1.7 [8].	see B 1.2	1 RSU sends out message, certificate needs to be verified
C-ITS station shall use ATs with the permissions defined in section B1.5 of '0190827_TF1_Security_report_v1.7 [8].	see B.1.5	many Values needs to be verified, depending on use case. Security expertise is needed
Receiving C-ITS station shall operate the initial verifications as described in the section B1.7.1 of 20190827_TF1_Security_report_v1.7 [8].	see B1.7.1	many Values needs to be verified, depending on use case. Security expertise is needed. Negative test cases also need to be provided
At each reception of message, the C-ITS station shall operate the signature verifications as described in the section B1.7.2 of 20190827_TF1_Security_report_v1.7 [8].	see B1.7.2	many Values needs to be verified, depending on use case. Security expertise is needed. Negative test cases also need to be provided