



C-ITS CROSS-BORDER TESTING: PCAP EX- CHANGE SPECIFICATION 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

Version	Date	Description, updates and changes	Status
0.1	10.04.2019	Marwane Ayaida: initiation of document for PCAP DENM Walter Zimmermann: Update for SPATEM and MAPEM Marwane Ayaida: Update for IVIM	draft
1.7.0	09.07.2020	Marwane Ayaida: Update Including new document name, versioning and update of references	Release
1.8.0	03.12.2020	Marwane Ayaida: Include the virtual testing session specification in the chapter 3.	Release
2.0.1	03.11.2021	Marwane Ayaida: update of the references, update of the introduction, reorganize the document to consider the two PCAP recording procedures, detail the certificates needed to be provided by the MS when storing PCAPs for VTS.	Release
2.0.3	21.04.2022	Marwane Ayaida: update of the references based on the Introductory document	Release
3.0.0	31.10.2025	Jan Schappacher: update of the release version and alignment with the WG2 reference document and new C-Roads Extended document template	Release

Index

Acronyms.....	4
References.....	5
1. Introduction.....	6
1.1. C-Roads platform for harmonisation of C-ITS deployment.....	6
1.2. Story board C-Roads C-ITS deployment documentation.....	7
1.3. Scope of this document.....	8
1.4. Deliverable Organization	8
2. Non synchronized PCAP Files Exchanging	9
2.1. Laboratory Interoperability Test Method	9
2.2. Environment Description.....	10
2.3. Generation of PCAP Files	10
2.3.1 Architecture.....	10
2.3.2 Generated messages	11
2.4. Exchanging the PCAP Files	16
2.5. Execution of the On-Lab Cross-Border Tests.....	16
2.5.1 Architecture.....	16
2.5.2 Messages Updates.....	18
2.6. Results Presentation of the Exchanged PCAP Files	19
3. Virtual Testing Session Specifications.....	20

Acronyms

Term	Meaning
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
IUT	Implementation Under Test
IVIM	In-Vehicle Information Message
IVS	In Vehicle Signage
ITS	Intelligent Transport Systems
ITS-S	ITS Station
MAPEM	MAP (topology) Extended Message
OBUE	Onboard Unit
PCAP	Packet CAPture
PTS	Physical Testing Session
MS	Member States
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
TTCN-3	Testing and Test Control Notation
UT	Upper Tester
V-ITS-S	Vehicle ITS Station (the socalled OBU)
VTB	Virtual Testing Session

Table 2 Acronyms

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 harmonized 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: PCAP Exchange Specification*. 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*.

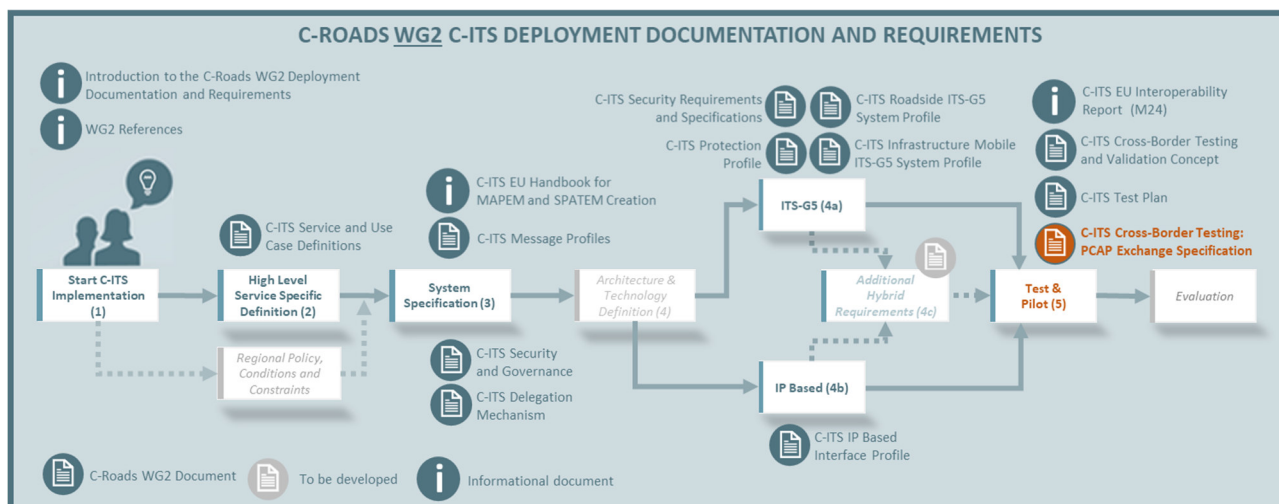


Figure 2: Highlight of WG2 document in complete story board

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 contains two procedures for generating and naming data packets (PCAP files) for a cross border exchange between C-Roads project partners. These procedures enable some type of interoperability testing by using various equipment before road tests. The first procedure, specified in the second chapter as “Non synchronized PCAP Files Exchanging”, must be used as an optional prerequisite for Cross-Border Physical Testing Sessions (PTS). It is mainly based on event-based recording. The objective of this procedure is to avoid the major interoperability issues before testing physically. The procedure to store PCAP files for these Virtual Testing Sessions (VTS) is specified in the chapter 3. The objective of VTS is to replace PTS, therefore the recording procedure was defined as drive based.

1.4. Deliverable Organization

This deliverable is organized as follows: the second chapter describes how PCAP log files could be generated and exchanged during a non-synchronized testing session, the way of tests’ execution and it shows how the On-Lab Cross-Tests interoperability results should be presented. The third one details the specification of the virtual testing sessions that are organized to replace the physical testing since the sanitary situation did not allow it.

2. Non synchronized PCAP Files Exchanging

This section describes the way of generating and exchanging PCAP files for the tests. In general, Figure 3 represents the architecture of PCAP files' exchanging.

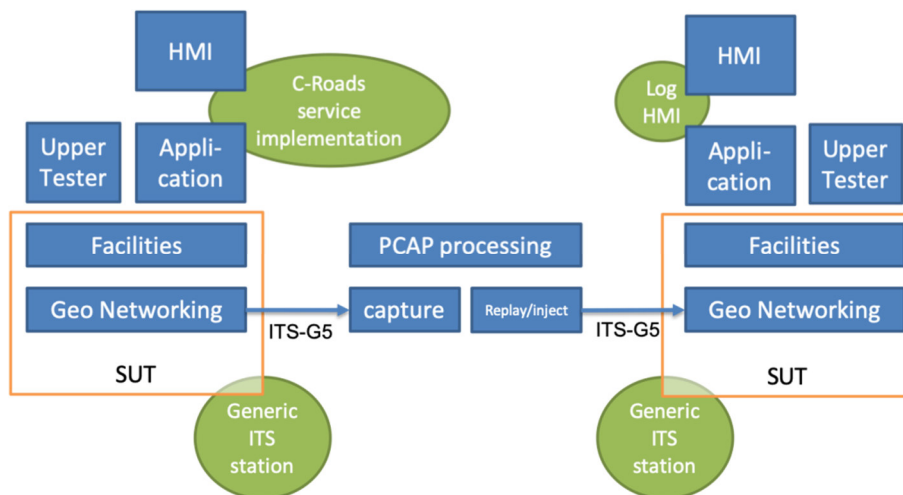


Figure 3: Architecture of the PCAP files generation

The PCAP file must be captured, processed and then replayed in order to verify the interoperability and to avoid the major issues that could threaten the interoperability.

2.1. Laboratory Interoperability Test Method

To ensure the interoperability between the Member States' (MS) equipments (OBU and RSU), we need to test first the communication between them. Since they are located in different places around Europe, we will start by testing the interoperability between them (using off-line principle). In this chapter, we will describe, first, to C-Roads partners how to proceed to generate the log files to be exchanged. These log files save the messages sent by any ITS-station X. After sending the log files, they can be rebroadcasted in another site in order to test if the equipment Y could receive and interpret them properly.

This chapter focuses only on exchanging PCAP files for packets without considering security. The security is excluded from these tests in this first procedure. Some other tests will target only this part and the second procedure specified in the next chapter will consider it also. Therefore, when we speak about generating packets in this chapter, readers must understand that packets do not include signature, security headers or certificates.

Such tests will allow us to ensure the same understanding of the ETSI standards and will facilitate the physical tests since some bugs could be identified and corrected at this step.

2.2. Environment Description

For these tests' purpose, we need these equipments:

- The equipment to be tested (SUT)
- Based on the option used:
 - An ETHERNET-G5 gateway, a computer to save the log files and a Wireshark tool
 - An ITS-G5 device (used for capturing)

2.3. Generation of PCAP Files

2.3.1 Architecture

Two options are proposed to generate the PCAP files:

- Option 1:

To generate the PCAP log files, we use the architecture presented in the Figure 4.

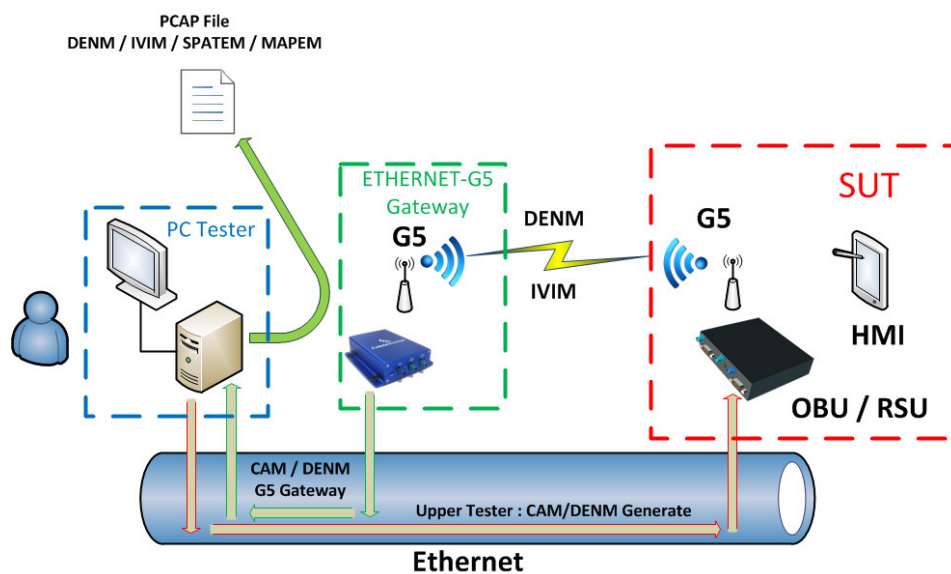


Figure 4: Architecture of the PCAP files generation with Option 1

The SUT must be stimulated (using the ETSI Upper Tester or the HMI) in order to start sending packets. The messages sent will be captured by the ETHERNET-G5 gateway.

These messages are transmitted to the PC using the ETHERNET link to the PC, where the Wireshark tool should be running. This tool is used then to save each message in a PCAP format. The files could be also generated directly on the SUT using for example the “tcpdump” command.

The PCAP file must have the format presented by the Figure 5.



Figure 5: Architecture of the PCAP files generation with Option 1

- Option 2:

To generate the PCAP log files, we use the architecture presented in the Figure 6.

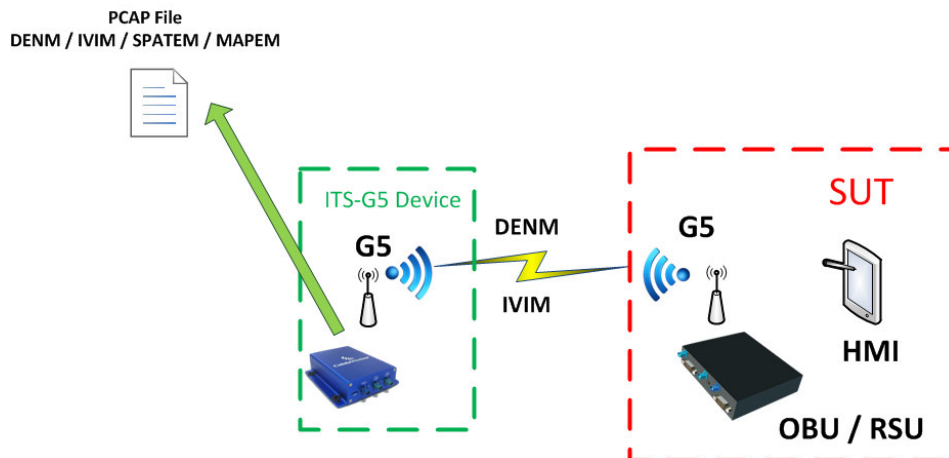


Figure 6: Architecture of the PCAP files generation with Option 2

These messages are directly saved at the RSU / R-ITS-S or by an additional ITS-G5 device capturing the messages on the air. Therefore, the files should have the format presented by the Figure 7.



Figure 7: Architecture of the PCAP files generation with Option 2

Note that, for the moment, the scope of the present release is also limited to ITS-G5 communication, i.e. Security and Hybrid communication are not yet included but will be in upcoming releases.

2.3.2 Generated messages

Each MS has to select for each type of message a representative Pilot Site if there are few. The messages generated have to come from only one equipment from one Pilot Site.

2.3.2.1 DENM

For DENM messages, **82** messages (as listed below) must be generated when using automated tool to generate. If testing is not automated, the test set can be limited to **20** messages by providing only one sub-cause code for each cause code, each in a separate file if it is managed by the MS. Each message/file presents one combination of cause code and sub-cause code for the Cross-Tests targeted in C-Roads. The cause codes and sub-cause codes used should be based on the C-Roads deliverable [C-Roads MP]:

1. Road Works Warning - Unknown: 3/0
2. Road Works Warning - Closure of part of a lane, whole lane or several lanes / Alert planned closure of road or a carriageway: 3/1
3. Road Works Warning - Closure of part of a lane, whole lane or several lanes: 3/2
4. Road Works Warning - Alert planned road works mobile: 3/3
5. Road Works Warning - Closure of part of a lane, whole lane or several lanes / Alert planned closure of road or a carriageway: 3/4
6. Road Works Warning - Closure of part of a lane, whole lane or several lanes: 3/5
7. Road Works Warning - Closure of part of a lane, whole lane or several lanes: 3/6
8. Road Works Warning - Rescue and recovery work in progress: 15/0
9. Road Works Warning - Rescue and recovery work in progress: 15/1

10. Road Works Warning - Rescue and recovery work in progress: 15/2
11. Road Works Warning - Rescue and recovery work in progress: 15/3
12. Road Works Warning - Rescue and recovery work in progress: 15/4
13. Road Works Warning - Rescue and recovery work in progress: 15/5
14. Road Works Warning - Rescue and recovery work in progress: 15/7
15. Road Works Warning - Slow vehicle: 26/0
16. Road Works Warning - Slow vehicle: 26/1
17. Road Works Warning - Slow vehicle: 26/2
18. Road Works Warning - Slow vehicle: 26/3
19. Road Works Warning - Slow vehicle: 26/4
20. Road Works Warning - Slow vehicle: 26/5
21. Road Works Warning - Slow vehicle: 26/6
22. Road Works Warning - Slow vehicle: 26/7
23. Road Works Warning - Slow vehicle: 26/8
24. Hazardous Location Notifications - Traffic condition: 1/0
25. Hazardous Location Notifications - Accident: 2/0
26. Hazardous Location Notifications - Accident: 2/1
27. Hazardous Location Notifications - Accident: 2/2
28. Hazardous Location Notifications - Accident: 2/3
29. Hazardous Location Notifications - Accident: 2/4
30. Hazardous Location Notifications - Accident: 2/5
31. Hazardous Location Notifications - Accident: 2/7
32. Hazardous Location Notifications - Adhesion: 6/0
33. Hazardous Location Notifications - Adhesion: 6/1
34. Hazardous Location Notifications - Adhesion: 6/2
35. Hazardous Location Notifications - Adhesion: 6/3
36. Hazardous Location Notifications - Adhesion: 6/4
37. Hazardous Location Notifications - Adhesion: 6/5
38. Hazardous Location Notifications - Adhesion: 6/6
39. Hazardous Location Notifications - Adhesion: 6/7
40. Hazardous Location Notifications - Adhesion: 6/8
41. Hazardous Location Notifications - Adhesion: 6/9
42. Hazardous Location Notifications - Surface condition: 9/0
43. Hazardous Location Notifications - Surface condition: 9/1
44. Hazardous Location Notifications - Surface condition: 9/4
45. Hazardous Location Notifications - Surface condition: 9/5
46. Hazardous Location Notifications - Surface condition: 9/7
47. Hazardous Location Notifications - Obstacle on the road: 10/0
48. Hazardous Location Notifications - Obstacle on the road: 10/1
49. Hazardous Location Notifications - Obstacle on the road: 10/2
50. Hazardous Location Notifications - Obstacle on the road: 10/3
51. Hazardous Location Notifications - Obstacle on the road: 10/4
52. Hazardous Location Notifications - Obstacle on the road: 10/5
53. Hazardous Location Notifications - Animal on the road: 11/0
54. Hazardous Location Notifications - Animal on the road: 11/2
55. Hazardous Location Notifications - Animal on the road: 11/4
56. Hazardous Location Notifications - Human presence on the road: 12/0
57. Hazardous Location Notifications - Human presence on the road: 12/1
58. Hazardous Location Notifications - Human presence on the road: 12/2
59. Hazardous Location Notifications - Wrong way driving: 14/2
60. Hazardous Location Notifications - Rescue and recovery work in progress: 15/0
61. Hazardous Location Notifications - Extreme weather condition: 17/1
62. Hazardous Location Notifications - Extreme weather condition: 17/2
63. Hazardous Location Notifications - Extreme weather condition: 17/4
64. Hazardous Location Notifications - Visibility: 18/0
65. Hazardous Location Notifications - Visibility: 18/1
66. Hazardous Location Notifications - Visibility: 18/2
67. Hazardous Location Notifications - Visibility: 18/3
68. Hazardous Location Notifications - Visibility: 18/4
69. Hazardous Location Notifications - Visibility: 18/5
70. Hazardous Location Notifications - Visibility: 18/6
71. Hazardous Location Notifications - Precipitation: 19/0
72. Hazardous Location Notifications - Precipitation: 19/1
73. Hazardous Location Notifications - Dangerous end of queue: 27/0
74. Hazardous Location Notifications - Stationary vehicle: 94/0
75. Hazardous Location Notifications - Stationary vehicle: 94/2
76. Hazardous Location Notifications - Stationary vehicle: 94/4





- 77. Hazardous Location Notifications - Emergency vehicle approach: 95/0
- 78. Hazardous Location Notifications - Emergency vehicle approach: 95/1
- 79. Hazardous Location Notifications - Emergency vehicle approach: 95/2
- 80. Hazardous Location Notifications - Collision risk: 97/1
- 81. Hazardous Location Notifications - Dangerous situation: 99/0
- 82. Hazardous Location Notifications - Dangerous situation: 99/1







A MS has to generate only the events that are managed by its pilot sites. Each file has to contain a unique packet and has to be named:




“C-Roads_DENM_CauseCode_SubCauseCode_Date_Country.pcap”.

2.3.2.2 IVIM

For IVIM messages, **14** messages must be generated each in a separate file. Each message/file presents one data elements combination for the Cross-Tests targeted in C-Roads as listed below. The details of the generated messages are defined in these different cases:

1. Case 1: The reference IVIM message:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11) 
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
2. Case 2: change serviceCategoryCode sub-case 1:
 - a. serviceCategoryCode: trafficSignPictogram/regulatory (12) 
 - b. PictogramCode (as defined in ISO/TS 14823): 12 / 542
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
3. Case 3: change serviceCategoryCode sub-case 2:
 - a. serviceCategoryCode: trafficSignPictogram/informative (13) 
 - b. PictogramCode (as defined in ISO/TS 14823): 13 / 660
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
4. Case 4: change serviceCategoryCode sub-case 3:
 - a. serviceCategoryCode: publicFacilitiesPictogram/publicFacilities (21) 
 - b. PictogramCode (as defined in ISO/TS 14823): 21 / 115
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
5. Case 5: change serviceCategoryCode sub-case 5:
 - a. serviceCategoryCode: ambientOrRoadConditionPictogram/ambientCondition (31)

- b. PictogramCode (as defined in ISO/TS 14823): 31 / 112 
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
- 6. Case 6: change serviceCategoryCode sub-case 6:
 - a. serviceCategoryCode: ambientOrRoadConditionPictogram/roadCondition (32)
 - b. PictogramCode (as defined in ISO/TS 14823): 32 / 111 
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
- 7. Case 7: include sign attributes:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11)
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / XXX (let as the tester's choice)
 - c. Sign attributes: yes (let as the tester's choice)
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
- 8. Case 8: change relevanceZone:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11)
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999 
 - c. Sign attributes: without
 - d. relevanceZone: 2
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
- 9. Case 9: change detectionZone:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11)
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999 
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 2
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
- 10. Case 10: change relevanceZone and detectionZone:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11)
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999 
 - c. Sign attributes: without
 - d. relevanceZone: 2
 - e. detectionZone: 2
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: without
- 11. Case 11: change lviStatus sub-case 1:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11)
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999 
 - c. Sign attributes: without
 - d. relevanceZone: 1

- e. detectionZone: 1
- f. lviStatus: 0 (New)
- g. extraText: without
- h. applicableLanes: without
- 12. Case 12: change lviStatus sub-case 2:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11) 
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 2 (Cancellation)
 - g. extraText: without
 - h. applicableLanes: without
- 13. Case 13: including extraText:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11) 
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: with extraText
 - h. applicableLanes: without
- 14. Case 14: including applicableLanes:
 - a. serviceCategoryCode: trafficSignPictogram/dangerWarning (11) 
 - b. PictogramCode (as defined in ISO/TS 14823): 11 / 999
 - c. Sign attributes: without
 - d. relevanceZone: 1
 - e. detectionZone: 1
 - f. lviStatus: 1 (Update)
 - g. extraText: without
 - h. applicableLanes: with applicableLanes

A MS has to generate only the events that are managed by its pilot sites. Each file has to contain a unique packet and has to be named:

“C-Roads_IVIM_CaseX_Date_Country.pcap”, where X is the case number as described above.

2.3.2.3 SPATEM

Each MS has to generate at least 9 SPATEM (minimum if possible 3 SPATEM for 3 different Intersections).

For SPATEM messages, each generated messages must be saved in a separate file.

Each message/file presents one use-case for the Cross-Tests targeted in C-Roads.

Each file has to contain a unique packet and has to be named:

“C-Roads_SPATEM_IntersectionX_Y_Date_Country.pcap”, where IntersectionX represents the number of the Intersection where the message was generated, and Y represents the number of the SPATEM message stored within this Intersection.

2.3.2.4 MAPEM

Each MS has to generate at least 9 MAPEM (minimum if possible 3 MAPEM for 3 different Intersections).

It would be better if the generated MAPEM and SPATEM messages will be stored at the same time and for the same Intersections. This will make testing easier.

For MAPEM messages, each generated messages must be saved in a separate file.

Each message/file presents one use-case for the Cross-Tests targeted in C-Roads.

Each file has to contain a unique packet and has to be named:

“C-Roads_MAPEM_IntersectionX_Y_Date_Country.pcap”, where IntersectionX represents the number of the Intersection where the message was generated, and Y represents the number of the MAPEM message stored within this Intersection.

2.4. Exchanging the PCAP Files

When exchanging PCAP log files, each test campaign must have its own file that describes the generation conditions. The description file has to be named in the same way as the PCAP file (“C-Roads_Date_Country.ods” or “C-Roads_Date_Country.xls”). The file must contain such a table with at least the following data (example):

Software Elements	Version	Comments
Capture Option	Option 1	Using Ethernet Gateway
DENM Protocol	1.3.2	DENM ETSI used standard
IVIM Protocol	1.2.2	IVIM ETSI used standard
SPATEM Protocol	1.3.2	SPATEM ETSI used standard
MAPEM Protocol	1.3.2	MAPEM ETSI used standard
Wireshark	1.12.8	Version of tool used
Wireshark ETSI Plugins	Wireshark-1.12.x/Windows/64bits	Version of plugins used

Table 3 Generation conditions of the PCAP file

The equipment could be used in the On-lab Cross-border tests only if it was already completely validated using the local tests of the origin country.

2.5. Execution of the On-Lab Cross-Border Tests

2.5.1 Architecture

The architecture is almost the same than for the log file generation. However, the data flow will be reversed. Therefore, two options are proposed to execute tests with the generated files:

- Option 1:

The Figure 8 describes the architecture when using Option 1.

A packet must be extracted from the PCAP log file. Then, it has to be broadcasted directly by the ETHERNET-G5 gateway. The message reception is verified using the OBU/RSU HMI or using the Upper Tester indication.

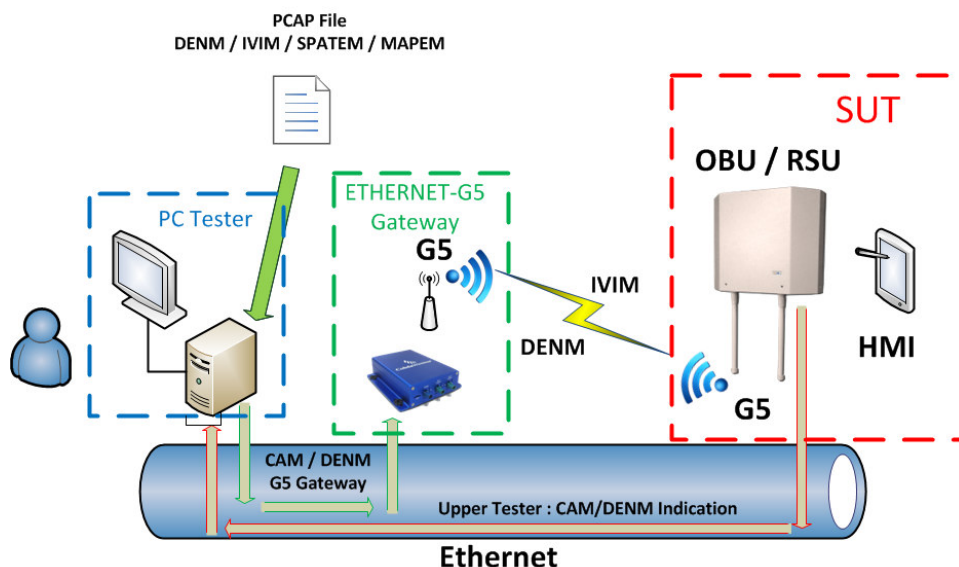


Figure 8: Architecture of the PCAP test execution with option 1

- Option 2:

The Figure 9 describes the architecture when using Option 2.

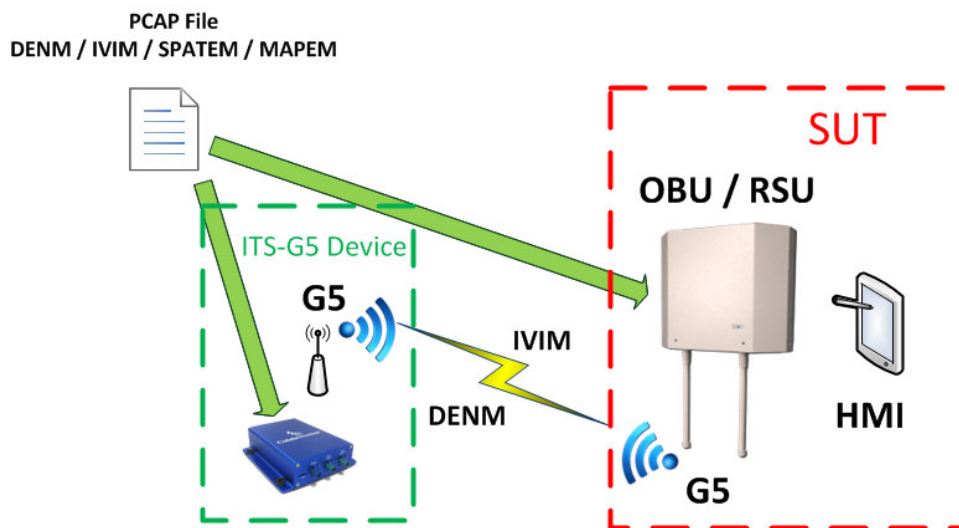


Figure 9: Architecture of the PCAP test execution with option 2

With Option 2, the capture may be either sent via ITS-G5 or fed directly into the SUT / RSU / OBU.

2.5.2 Messages Updates

The messages saved in the log files could not be sent as they are. In fact, several fields will not be valid. More specifically, those relating to the time and the position. Thus, these data, usually stored in the message-header, must be modified before being sent back. This will be the case whenever using the Capture Option 1 or 2. To automate the execution of the tests, an application to be installed on the PC Tester will be provided. This application will manage only the Capture Option 1 and will not work for the Option 2. A tutorial of the usage of this application will follow and will be added as Annex to this deliverable. Some of these fields are cited below:

- For DENM messages:
 - DENM.denm.management.eventPosition.latitude
 - DENM.denm.management.eventPosition.longitude
 - DENM.denm.management.detectionTime
 - DENM.denm.management.referenceTime
- For IVIM messages:
 - IVIM.ivi.ManagementContainer.timestamp
 - IVIM.ivi.ManagementContainer.validFrom (if present, since optional)
 - IVIM.ivi.ManagementContainer.validTo
 - IVIM.ivi.GeographicLocationContainer.referencePosition
- For SPATEM messages:
 - Modifying the position of the vehicle to be close to the intersection
 - SPATEM.IntersectionStateList.IntersectionState.timeStamp
- For MAPEM messages:
 - Modifying the position of the vehicle to be close to the intersection
- For GEONET messages:
 - GeoAreaPos.LatitudeLongitude
 - GeoAreaPos.Longitude
 - Geobroadcast.latitude
 - Geobroadcast.longitude
 - Geobroadcast.source position vector.timestamp.

2.6. Results Presentation of the Exchanged PCAP Files

The results of the Cross-Border PCAP exchange must be communicated in tabular form as follows:

PCAP File	Origin Country	Testing Country	Interoperability results				Comments
			Success	Fail	Inconclusive	Not Tested	
C-Roads_DENM_3_0_01012020_France.pcap	France	Slovenia	X				
C-Roads_DENM_2_2_01012020_France.pcap				X			Fail because...
C-Roads_DENM_10_4_01012020_France.pcap						X	Not possible to test because...
C-Roads_DENM_94_2_01012020_France.pcap			X				
C-Roads_DENM_3_0_01012020_Germany.pcap	Germany	Slovenia			X		Inconclusive because...
C-Roads_DENM_2_2_01012020_Germany.pcap				X			Fail because...
C-Roads_DENM_10_4_01012020_Germany.pcap			X				
C-Roads_DENM_94_2_01012020_Germany.pcap				X			Fail because...

Table 4 Example of some results of the Cross-Border PCAP exchange

3. Virtual Testing Session Specifications

This section describes the way of organizing virtual testing sessions. These sessions target to replace the physical testing ones if the latter are not possible due to the sanitary situation. Thus, they have been specified to be as close as possible to physical tests and to cover a majority of the aspects that could be tested physically.

The virtual testing session will be scheduled on the same timeslot of the physical ones. It has to be organized in the same way as the physical one. Each hosting MS will organize its own session that will be open to the other MS and to the third parties such as C2C members. The hosting MS will have to store all the messages sent from its RSUs and ROVs using the PCAP format files as presented in the previous chapter. Then, it has to share them with the visiting MS to test them remotely. After that, the feedbacks of these tests have to be sent to the hosting MS. This will allow it to organize an online web-meeting, which will be scheduled to exchange about the different issues that were identified during these tests. Finally, the hosting MS must provide a testing report that will summarize all the results of these virtual tests.

For more details, the hosting MS has to store the PCAPs while driving through its On-Road Test Track of its Pilot Site. To do so, there are different steps:

- Drive through the Test Track with a vehicle equipped with an OBU
- Log all the sent and received messages (CAM, DENM, IVIM, SPATEM, MAPEM, SSRM, SSEM, etc.) by the OBU and store them as PCAP files.

Then, the hosting MS has to share with the visiting MS:

- All the stored PCAPs
- The exact positions of all the expected events
- The exact positions of all the RSUs that are used in the virtual testing
- The PCAPs have to be provided 4 weeks before the virtual session

On the other side, after receiving the PCAPS, the visiting MS must replay them virtually. To do so, it must implement these functionalities:

- Online PCAPs replaying which is a mandatory feature for such tests
- Modification of the receiver's location:
 - Recommended solution: following the virtual path given by the hosting MS that is included in the PCAPs (extracted from CAMs)
 - If not possible: modifying manually the position of the receiver
- Managing the Validity time of the receiver:
 - Recommended solution: modifying automatically the timing from PCAPs (extracted from CAMs)
 - If not possible: modifying manually the timing of the receiver

Concerning the security, it has to be enabled by the sender (hosting MS) when storing the PCAPs. Therefore, the stored messages need to be secured to allow to test the security implementation by the

visiting MS. Therefore, the usage of the security when executing the tests virtually is recommended if the receiver manages it. Otherwise, the receiver must disable it and ignore the security fields.

Besides, the hosting MS must distribute all its certificates used to generate the PCAPs in order to be used by the visiting MS for validating the security implementation when replaying the PCAPs. For the security verifications, the replaying tool requires all the trust chain elements of the sender. This includes:

- The AA certificate (to verify the permissions and signature of the AT used to sign the message)
- The RCA CRL (to verify that the AA has not been revoked)
- The RCA certificate (to verify the permissions and signature of the AA certificate and the CRL)
- The LO ECTL (to verify that the RCA can be trusted)
- The TLM certificate (to verify the signature of the ECTL)

In general, all these elements are public:

- AA, CRL, RCA are available on the RCA Distribution Center (DC). Provision of these elements to receiving testers can be done under 2 different ways:
 - By going to the DC whose URL can be provided by the sender or retrieved from the LO ECTL (since December 2020)
 - In case stations cannot automatically retrieve the required elements and several versions have been used (e.g. 2 different AAs have been involved in tests), the sender should point the appropriate elements to be used.
 - By attaching them directly to the PCAP files
- LO ECTL (<https://cpoc.jrc.ec.europa.eu/ECTL.html>) and TLM certificate (<https://cpoc.jrc.ec.europa.eu/TLMCertificates.html>) are available on the CPOC. Like RCA elements, they can be provided directly in PCAP files.

Despite that all these elements could be retrieved online, TF5 recommends the hosting MS to attach them to the PCAPs that are provided on the Cloud. This will allow any tester to replay and tests the PCAPs at any time since the certificates provided online could be replaced and not available anymore.

The visiting MS must send a report containing its feedbacks from these tests to the hosting MS one week before the virtual meeting to allow it to prepare well this meeting.

All the previous statements are applicable for RSUs. However, if the tests concern V_{ro} s, the mechanism is almost the same. In this specific case, no need to use another vehicle by the visiting MS. Thus, the V_{ro} moves and stores its own messages in PCAP files. These PCAPs could be used on the same way than previously with the OBU in the case of RSUs.

For these tests, the hosting MS is responsible of the organization of the virtual testing session. Therefore, it has to:

- Send the invitation to all the visiting MS and third parties.
- Give a remote access connection for the online Web-meeting.
- Collect the results from the visiting MS.
- Provide a report for the full virtual testing session.

The proposed planning for this type of virtual testing session is:

- 1 day to discuss online the results of the PCAPs tests
- 1 week to debug
- 1 day to re-test, wrap up and collect the results

The following Figure 10 summarizes the timeline of these virtual testing sessions:

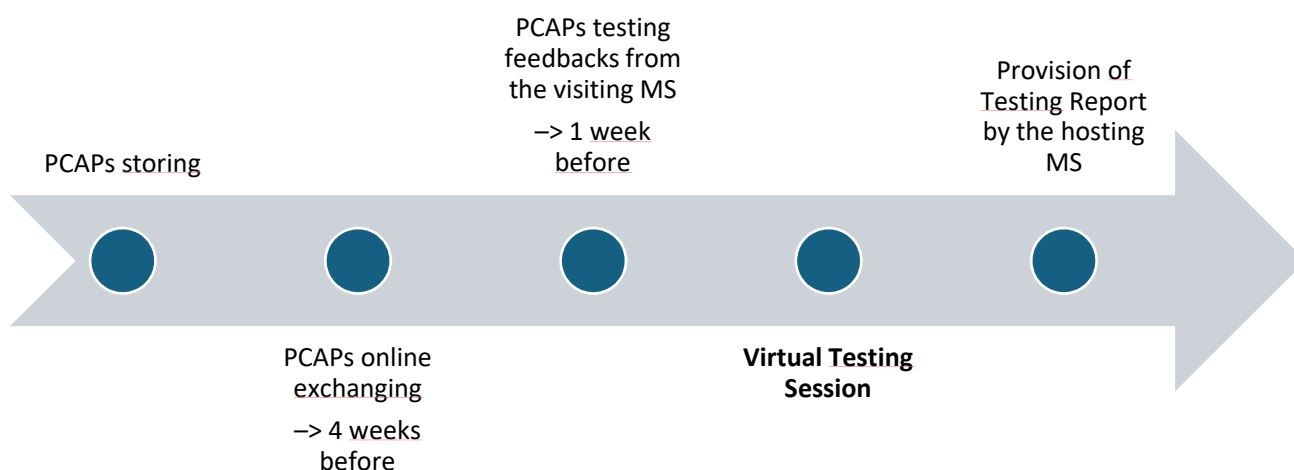


Figure 10: Proposed timeline for VTS