# D5.2 Validation methodology

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# Control sheet

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| V0.1 | 17/02/2023 | Peter Schmitting (FSCOM) | Structure built, aggregation of all UC inputs |
| V0.2 | 05/03/2023 | Peter Schmitting (FSCOM) | Continuation on UC related TCs, first version public acceptance validation methodology |
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# ABBREVIATIONS

| Abbreviation | Definition |
|---|---|
| 5G-IANA | 5G Intelligent Automotive Network Applications |
| 5G-PPP | 5G Public Private Partnership |
| AI | Artificial Intelligence |
| AF | Application Function |
| AGV | Automated Guided Vehicle |
| AOEP | Automotive Open Experimental Platform |
| API | Application Programming Interface |
| AR | Augmented Reality |
| ATI | Affinity for Technology Interaction |
| AV | Autonomous Vehicle |
| CD | Continuous Delivery |
| CE | (Gitlab) Community Edition |
| CI | Continuous Integration |
| CPU | Central Processing Unit |
| DL | Downlink |
| DML | Distributed Machine Learning |
| DMLO | DML Orchestrator |
| DN | Data Network |
| DoA | Description of Action |
| E2E | End-to-End |
| EC | European Commission |
| ETSI | European Telecommunications Standards Institute |

| | |
|---|---|
| FL | Federated Learning |
| FOV | Field-of-View |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| HMD | Head Mounted Display |
| HMI | Human Machine Interface |
| HTTP | Hypertext Transfer Protocol |
| ICMP | Internet Control Message Protocol |
| ID | Identifier |
| IPC | Inter-Process Communication |
| KPI | Key Performance Indicator |
| LCM | Life Cycle Management |
| MANO | Management and Orchestration |
| MTBF | Mean Time Between Failure |
| MCAD | Manoeuvre Coordination for Autonomous Driving |
| MEC | Multi-access Edge Computing |
| ML | Machine Learning |
| MOS | Mean Opinion Score |
| MTTR | Mean Time To Repair |
| nApp | network Application, a composition of atomic application and network function components |
| NF | Network Function |
| NW | Network |
| OS | Operating System |
| PU | Public |

| | |
|---|---|
| OBU | On-Board Unit |
| QoE | Quality of Experience |
| QoS | Quality of Service |
| RAN | Radio Access Network |
| RSTP | Rapid Spanning Tree Protocol |
| RSU | Road-Side Unit |
| RTT | Round-Trip-Time |
| SME | Small and Medium Sized Enterprise(s) |
| TC | Test Case |
| UC | Use Case |
| UDP | User Datagram Protocol |
| UE | User Equipment |
| UL | Uplink |
| UPF | User Plane Function |
| VBT | Virtual Bus Tour |
| VNF | Virtual Network Function |
| vOBU | Virtual On-Board Unit |
| VR | Virtual Reality |
| WP | Work Package |

# EXECUTIVE SUMMARY

The present document is deliverable D5.2 'Validation methodology' of the 5G-IANA project. It has been developed by task T5.1 'Validation methodology and plan'. The main objective of the deliverable is to provide a common validation methodology and technique that may be used not only within the Use Case (UC) deployments of the 5G-IANA project partners but also by third party experimenters wanting to use the 5G-IANA platform for experimentation purposes.

Similar to the work performed for D5.1 'Initial validation KPIs and metrics', a top-down approach was chosen i.e., defining first the UC related Test Case (TC) descriptions (see tables in chapter 3). The TCs cover functional aspects leading to Pass and Fail verdicts based on the tested behaviour and also the validation of the D5.1-defined KPIs.

In view of the platform testing phase which will validate software modules in a test environment and evaluate their suitability for integration into the final Automotive Open Experimental Platform (AOEP), two types of KPIs have been defined in chapter 2 for the 5G-IANA platform. The Reliability and Availability KPIs which can be used to validate the platform for its stability and its usability, and the Service Deployment and Provisioning time KPIs which can be used to validate the platform against the users' response.

The 5G-IANA Test Automation framework approach is introduced in chapter 4 describing a first concept for the automatic execution of one or several test suites, one per nApp or vertical service. The nApps tests suites will be part of the nApp package, and the 5G-IANA test automation framework execution will be triggered by a composer to validate the onboarding of nApps into the nApps catalogue.

In addition to the technical validation aspects (Chapters 2 - 5) which provide the technology base for task T5.2 'nApps validation and demonstration activities', also the public acceptance validation methodology is defined in the present deliverable in chapter 6. This methodology, based on surveys tailored for different stakeholder groups, will act as base for task 5.3 'Public acceptance'.

The present deliverable has been developed in cooperation with all WP5 partners before starting the actual validation phase. Deployment of the described methodologies in the future 5G-IANA activities on platform and UC deployment and validation may lead to further refinements of the methodology which will be reported in subsequent WP5 deliverables.

# 1. INTRODUCTION

## 1.1. 5G-IANA concept and approach

5G-IANA aims at providing an open 5G experimentation platform, on top of which third-party experimenters, i.e., SMEs in the Automotive vertical sector will have the opportunity to develop, deploy and test their services. The provided Automotive Open Experimentation Platform (AOEP) is a set of hardware and software resources that provides the computational and communication/transport infrastructure as well as the management and orchestration components, coupled with an enhanced nApp Toolkit tailored to the Automotive sector, for simplifying the design and onboarding of new nApps. 5G-IANA exposes to experimenters secured and standardized Application Programming Interfaces (APIs) for facilitating all the different steps towards the production stage of a new service. 5G-IANA targets different virtualization technologies integrating different Management and Orchestration (MANO) frameworks for enabling the deployment of end-to-end network services across different segments (vehicles, road infrastructure, Multi-access Edge Computing (MEC) nodes and cloud resources). 5G-IANA nApp toolkit is linked with an Automotive Virtual Network Functions (VNFs) Repository including an extensive portfolio of ready-to-use and openly accessible Automotive-related VNFs and nApp templates, that are available for SMEs to use and develop new applications. Finally, 5G-IANA develops a Distributed Machine Learning (DML) framework, that provides functionalities for simplified management and orchestration of collections of Machine Learning (ML) service components and thus, allows ML-based applications to penetrate the Automotive world, due to its inherent privacy-preserving nature. 5G-IANA will be demonstrated through seven Automotive-related use cases in two 5G Stand Alone (SA) testbeds. Moving beyond technological challenges, and exploiting input from the demonstration activities, 5G-IANA will identify and validate market conditions for innovative, yet sustainable business models for the AOEP platform, supporting a long-term roadmap towards the pan-European deployment of 5G as a key advanced Automotive services enabler.

## 1.2. Purpose of the deliverable

Task T5.1 ‘Validation methodology and plan’ is the validation design task that is applicable to all Intelligent nApps to be validated and demonstrated at two 5G experimentation platforms. The task started with the definition of research questions, metrics/KPIs, and acceptance criteria for the validation of the components/mechanisms described in D5.1 ‘Initial validation KPIs and metrics’.

The purpose of the present deliverable is to provide the validation methodology to be used for measuring the efficiency of the 5G-IANA architecture and the corresponding system performance through the use of the 5G-IANA experimentation platform. It includes also the definitions for a methodology to automate and homogenize testing and validation steps. The ultimate goal is to describe a common validation methodology and technique that may be used not only within the Use Case (UC) deployments of the 5G-IANA project partners but also by third party experimenters wanting to use the 5G-IANA platform for experimentation purposes where different UCs and challenges are evaluated. The deliverable is the base for the work of T5.2 'nApps validation and demonstration activities'.

Furthermore, the deliverable contains definitions of user acceptance/social inclusion metrics for the assessment of the acceptability of different stakeholders involved in the development, deployment, and use of 5G technology. This part defines the base for T5.3 'Public acceptance'.

## 1.3. Intended audience

The dissemination level of this deliverable is "public" (PU). It is primarily aimed to be the reference document to be used by the 5G-IANA Consortium Members during the validation phases of the 5G-IANA project. Furthermore, this deliverable is addressed to any interested reader (i.e., public dissemination level) who wants to be informed about 5G-IANA validation methodology and especially third-party experimenters intending to use the open 5G-IANA experimentation platform.

# 2. AUTOMOTIVE OPEN EXPERIMENTAL PLATFORM (AOEP) VALIDATION

## 2.1. Introduction

The AOEP Platform is composed by a set of components which provides unique capabilities and functionalities to compose and deploy Vertical Services for the automotive sector. As stated in D5.1 [1], the platform will go through two development and integration cycles which provide a stable platform to be used and to be validated.

From M25, the platform will start the validation phase which will consist, from one side in a KPI validation reported below in 2.2 and 2.3, from the other side the collection of the users' feedbacks on using the platform, to improve and to simplify the platform and the user's interaction.

This phase's testing will be primarily focused on validating software modules using a test environment and assessing their suitability for incorporation into the final experimental testbed. This will comprise certain features and functions relating to the time required for service deployment, the use of operational resources, the time required for reconfiguration, as well as some quality measurements relating to the use of the platform and the onboarding procedure.

As stated in D5.1 [1], the AOEP needs to be validated with specific categories of KPIs:

- Reliability and Availability KPIs
- Service deployment and provisioning time KPIs

These categories can be measured in completely automatic way and each AOEP component contributes to the validation activities depending by its functionality.

## 2.2. Reliability and Availability KPIs validation

As stated in D5.1 [1], the Reliability and Availability KPIs are used to validate the platform for resilience and stability. The validation methodology will retrieve the logs of the components of the platform and will extract the necessary metrics as stated in section 2.6.2 of D5.1 [1].

### 2.2.1. Reliability KPI

The concept of reliability refers to the degree of confidence we can have in a system's ability to remain operational, whether it is an application or a distributed service. A system that is highly reliable can continue running without assistance for a longer period of time before encountering issues or requiring human intervention. Table 1 describes the Reliability KPI test case which involves the Mean Time Between Failure (MTBF) calculated as Total operation time / Number of failures.

**Table 1, TC_KPI_AEOP_01, Reliability**

| Test Case ID | TC_KPI_AEOP_01 |
|---|---|
| Summary | The reliability is measured using cycles of uninterrupted working intervals (uptime), followed by a repair period after a failure has occurred (downtime). |
| UC number or AOEP | AOEP |
| KPI | Reliability, see D5.1 2.6.2 |
| Test objective | To check if the AOEP platform is stable. |
| Pre-conditions | The AOEP is deployed on the target testbed. |
| Targeted result | The AOEP is stable, and the value measured as MTBF = total operational time / Number of failures is higher than the KPI value. |
| Test procedure | 1. The platform is deployed and is up and running on the target testbed.<br>2. The platform is used by the users.<br>3. Log data are collected to be evaluated. |
| Collecting data | Retrieves specific log inside each component.<br>The test will be repeated several times with increasing usage time.<br>The exact number of test runs and the applicable usage times will be determined during the active validation phase. |
| Test verdict | if the Reliability of the platform is higher than the KPI value: PASS<br>if the Reliability of the platform is lower than the KPI value: FAIL |

### 2.2.2. Availability KPI

As stated in D5.1 [1], the reliability is a function of the availability: a component can be available but not reliable. This means that a component may be considered available yet lack reliability, indicating that it can achieve high quality only if it possesses both good availability and reliability. Table 2 presents the Availability KPI test case which involves the Mean Time Between Failure (MTBF) and the Mean Time To Repair (MTTR) metrics. This last metric is calculated as Total repair time / Number of repairs.

**Table 2, TC_KPI_AEOP_02, Availability**

| Test Case ID | TC_KPI_AEOP_02 |
|---|---|
| Summary | The availability defines the time the platform is running. |
| UC number or AOEP | AOEP |
| KPI | Availability, see D5.1 2.6.2 |
| Test objective | To check if the AOEP platform is available. |
| Pre-conditions | The AOEP is deployed on the target testbed |
| Targeted result | The AOEP is available and the calculated value of Availability = MTBF / (MTBF+MTTR) = Uptime / (Uptime + Downtime) |
| Test procedure | 1. The platform is deployed and is up and running on the target testbed.<br>2. The platform is used by the users.<br>3. Log data are collected to be evaluated. |
| Collecting data | Retrieves specific log inside each component.<br>The test will be repeated several times with increasing usage time.<br>The exact number of test runs and the applicable usage times will be determined during the active validation phase. |
| Test verdict | if the Availability of the platform is higher than the KPI value: PASS<br>if the Availability of the platform is lower than the KPI value: FAIL |



## 2.3. Service deployment and provisioning time KPI validation

These KPIs are used to validate the usability, the simplicity and the goodness of the platform against Vertical Service developers. The 5G-IANA validation framework retrieves and analyses the logs of each component of the platform to determine if the KPIs, defined in D5.1 [1] are valid.

Since the validation of the following KPIs depends on several unpredictable factors, like the user expertise which impact on the time required to interact with the platform, the validation will be repeated using different user categories (beginners, medium-expertise, experts) multiple times and the average of the collected result will be used to validate the platform against the KPIs.

### 2.3.1. Service Creation Time

The Service Creation Time shows how long it takes the AOEP end user to build the required Vertical Service chain. The performance of the AOEP's nApp Toolkit component is specifically evaluated, along with how its exposed functions aid in the process of developing a new Vertical Service chain. In Table 3 a validation methodology is reported to measure the Service creation time.

**Table 3, TC_KPI_AOEP_03, Service Creation Time**

| Test Case ID | TC_KPI_AOEP_03 |
|---|---|
| Summary | The nApp package is onboarded correctly and stored in the 5G-IANA repository. |
| UC number or AOEP | AOEP |
| KPI | KPI_SL_AOEP_01 |
| Test objective | To check if the AOEP platform is suitable to create a Vertical Service. |
| Pre-conditions | The AOEP is reachable by the Vertical Service Developer, the nApp Catalogue and the Vertical Service Composition & Customization components are up and running, the docker images which will be used as atomic components are already uploaded in the centralized registry. |
| Targeted result | The nApp is graphically created and successfully onboarded on the nApp catalogue. |
| Test procedure | 1. The vertical service developer opens the AOEP GUI and starts creating atomic components using the interfaces provided by the Composer.<br>2. The vertical service developer links together the atomic component using graph methodology and specifying the interfaces to be used.<br>3. The vertical service developer clicks on the 'Onboard button'.<br>4. The Vertical Composer pack the information in nApp template and call the nApp catalogue Rest API.<br>5. The Vertical Composer receives a successful message when the nApp is onboarded. |
| Collecting data | Retrieves specific log inside each component.<br>The test will be repeated for several users, multiple times for each user. The exact number of users and the number of test runs per user will be determined during the active validation phase.<br>The validation framework will extract some metrics from the logs to calculate the average and maximum value. |
| Test verdict | if the sum of the time spent by each component is lower than the KPI value: PASS<br>If the sum of the time spent by each component is higher than the KPI value: FAIL |

The validation framework will retrieve the logs of each component involved in this action:

- nApp Catalogue

- Vertical Service Composition & Customization

and will calculate the total time involved for a Service Creation summing together the various steps. After all the onboarding operations are done, the validation framework will calculate the average and the maximum time of the operation.

### 2.3.2. Service Provisioning Time

The service provisioning time refers to the time from when a created service is triggered to be deployed on top of programmable resources until the time the deployment has ended successfully. It is important to state that the measurement concerns a successful deployment and in case of error during the deployment, there are specific error messages for each particular phase of the deployment that appear and alert the end user of the failure.

**Table 4, TC_KPI_AOEP_04, Service Provisioning Time**

| Test Case ID | TC_KPI_AOEP_04 |
|---|---|
| Summary | The process when an nApp graph deployment is triggered on top of specified programmable resources until the deployment finishes successfully. |
| UC number or AOEP | AOEP |
| KPI | KPI_SL_AOEP_02 |
| Test objective | To measure the time AOEP platform takes to deploy a specific Vertical Service and to test whether it is below a maximum deployment time. |
| Pre-conditions | The nApp graph to be deployed is stored in the nApp Catalogue along with the definition all of its atomic components.<br>The target environment is reachable from the Application Orchestrator.<br>The Application Orchestrator is reachable by the Vertical service developer. |
| Targeted result | The nApp graph is deployed on specified programmable resources (edge/core) successfully. |
| Test procedure | 1. The vertical service developer selects a particular nApp graph (stored on the nApp catalogue) to deploy.<br>2. The vertical service developer provides a name for this instance of the nApp graph.<br>3. The vertical service developer provides deployment and runtime constraints for the components. These constraints are related with the performance of the nApp (or part of the nApp) and expressed in |

| | |
|---|---|
| | network and resource requirements. The user can also select the deployment location from a list of supported deployment sites.<br>4. The vertical service developer opens the AOEP GUI and triggers the deploy button to start the process.<br>5. The deployment phase starts with the Slice Intent Handler (NOD) packing all the previous requirements in a descriptor that is sent to the Slice Management & Resource Orchestration.<br>6. Slice Management & Resource Orchestration allocates the specified resources in order to facilitate the service deployment and operation.<br>7. Slice Management & Resource Orchestration replies back to the Slice Handler (NOD) all the connection details from the allocated programmable resources.<br>8. Deployment Manager (NOD) connects to the programmable resources and deploys the services. |
| Collecting data | Retrieves specific logs with time intervals starting from the time the vertical end user hits the deploy button until the deployment is finished. |
| Test verdict | If deployment time is less than the maximum deployment time: PASS<br>If deployment time is more than the maximum deployment time: FAIL |

### 2.3.3. Service Modification time

The service modification time shows the adaptation speed of the vertical service to the changes that happen in the environment. Several components of the AOEP platform are involved, like the DMLO that shapes the need to scale in / scale out the vertical service resources, as described in Table 5.

**Table 5, TC_KPI_AOEP_05, Service Modification Time**

| Test Case ID | TC_KPI_AOEP_05 |
|---|---|
| Summary | The running vertical service scales its nApps reconfiguring the service. |
| UC number or AOEP | AOEP |
| KPI | KPI_SL_AOEP_03 |
| Test objective | To check if the AOEP platform is suitable to scale in / scale out a Vertical Service. |
| Pre-conditions | The vertical service should be reachable by the whole AOEP platform. All the components must be up and running. For scaling up procedure, the computing resources to scale out the vertical service must be available. |
| Targeted result | The vertical service is corrected scaled in or scaled out. |
| Test procedure | 1. The monitoring platform or the DMLO figure out the needs to scale in / scale out a vertical service and ask the policy manager to do that. |

| | |
|---|---|
| | 2. The policy manager asks VAO to scale in / scale out the vertical service.<br>3. The VAO send the slice intent to the Slice manager & Resource Orchestrator.<br>4. The Resource Orchestrator updates the corresponding resource quota on the namespace.<br>5. The Resource Orchestrator send back the new kube.config to the VAO.<br>6. The VAO scale up / scale down the service directly on the Kubernetes master. |
| Collecting data | Retrieves specific log inside each component.<br>The test will be repeated for several vertical services, multiple times for each service. The validation framework will extract some metrics from the logs to calculate the average and maximum value. |
| Test verdict | Since the target KPI value is not defined in the [5], we assume the same boundary of the service provisioning time, with a targeted maximum value set to 5 minutes.<br>If the sum of the time spent by each component is lower than 5 minutes: PASS<br>If the sum of the time spent by each component is higher than 5 minutes: FAIL |

### 2.3.4. Service Termination Time

Service Termination Time refers to the time interval between the time the request for un-deploying a service gracefully is triggered until the time the service is deleted and the allocated programmable resources are not occupied any more (deprovisioned).

**Table 6, TC_KPI_AOEP_06, Service Termination Time**

| Test Case ID | TC_KPI_AOEP_06 |
|---|---|
| Summary | The AOEP deletes a service and deprovisions the occupied programmable resources. |
| UC number or AOEP | AOEP |
| KPI | KPI_SL_AOEP_04 |
| Test objective | To check that the AOEP platform deprovisions resources within a maximum time. |
| Pre-conditions | The vertical service provider selects to un-deploy an already deployed nApp.<br>The nApp is deployed on a specific environment. |

| | |
|---|---|
| | The Deployment Manager and the Slice Handler are up and running. |
| Targeted result | The vertical service is deleted, and the occupied programmable resources are released. |
| Test procedure | 1. The Vertical Service provider selects a deployed nApp to delete.<br>2. Deployment Manager (NOD) access the respective programmable resources where the nApp is deployed and deletes the service.<br>3. After the service is deleted, Slice Handler (NOD) sends to the Slice Management a notification that the nApp with certain id is deleted.<br>4. Slice Management seeks in its internal database the nApp id and the assigned programmable resources.<br>5. Slice Management and Resource Orchestration de-provisions the respected assigned programmable resources. |
| Collecting data | Retrieves logs with the time reported in intervals. The time starts counting when the user hits the delete button of an nApp and finishes when the Deployment Manager removes the running services. |
| Test verdict | If the deletion request does not exceed the specified KPI: PASS<br>If the deletion request does exceed the specified KPI: FAIL |

## 2.4. DMLO Client Selection

### 2.4.1. Introduction

As described in D2.1 [2] and D3.1 [3], the Distributed Machine Learning Orchestrator (DMLO) component of the platform is responsible for supporting the client selection process in the context of Federated Learning (FL) enabled services. This constitutes a process taking place after the deployment of the service resulting in runtime service modifications. The modifications correspond to the adaptation of the set of active far edge nodes (FL clients) subject to runtime conditions. Validation in this case focuses on the two main sub-processes realizing/supporting client selection, namely Far-Edge Node Selection and Activation corresponding to Steps 5 and 6, respectively in the client selection process (D3.1 [3]).

### 2.4.2. DMLO KPIs

DMLO KPIs had not been covered in D5.1 [1]; therefore, the following corresponding KPIs to more concisely define these processes and further guide the validation process are introduced.

**Table 7, KPI_SL_AOEP_05 – Far-Edge Node Selection Time**

| Service Modification Time | KPI_SL_AOEP_05 |
|---|---|

| | |
|---|---|
| Description | Time consumed by the platform to identify the most appropriate far-edge node set according to the selection criteria defined by the vertical service/application. |
| Context/Use Case | UC6 and any Federated Learning based application. |
| Where to observe/measure/monitor | This KPI can be measured by processing relevant events reported by the logging system of the DMLO. |
| How to observe/measure/monitor | This KPI is measured by comparing the timestamps of the following events: (i) reception of the corresponding client selection request by the Aggr Node; (ii) transmission of the far-edge node set information (response) by the DMLO. Though the KPI focuses on the duration of the process (performance), it is also important that the corresponding validation/evaluation process further focuses on the correctness of the operation i.e., that the return far-edge node set is actually the correct one according to the current status and the selection criteria. This links the process to the component-level unit testing and validation process focused on specific components of the platform such as the Resource Inventory and the Monitoring & Analytics. |
| How to evaluate | This KPI corresponds to a component internal (DMLO) process and is actually based on information asynchronously collected by the far edge nodes and the Resource Inventory. As such, the performance level evaluation can be supported by the definition of a sub-second target value. |

**Table 8, KPI_SL_AOEP_06 – Far-Edge Node Activation Time**

| Service Modification Time | KPI_SL_AOEP_06 |
|---|---|
| Description | Time consumed by the platform to activate the Training Node AF instances on the set of far-edge nodes (OBUs) finally selected by the Aggr Node. |
| Context/Use Case | UC6 and any Federated Learning based application. |

| | |
|---|---|
| Where to observe/measure/monitor | This KPI can be measured by processing relevant events reported by the logging system of the DMLO. |
| How to observe/measure/monitor | This KPI is measured by comparing the timestamps of the following events: (i) reception of the corresponding final client selection decision by the Aggr Node; (ii) transmission of the acknowledgement (response) message by the DMLO. Though the KPI focuses on the duration of the process (performance), it is also important that the corresponding validation/evaluation process further focuses on the correctness of the operation i.e., that the Training Node AFs have indeed been correctly activated in the correct set of far-edge nodes. This links the process to the service provisioning validation/evaluation and in particular to the VAO sub-process of AF orchestration (LCM), which in this particular runtime modification phase relates to the operation of the Policy Execution component (and the corresponding unit testing). |
| How to evaluate | This KPI depends on the completion of the actual activation LCM event by the Policy Execution component. Initial evaluation can be based on a rough definition of a target value in correspondence with the Service Provisioning Time KPI i.e., in the order of 5 min. |

### 2.4.3. DMLO TC tables

Given the above KPI definitions, the test cases designed for the validation of the DMLO-specific AOEP functionality are presented as follows.

**Table 9, TC_KPI_AOEP_07, Far-Edge Node Selection Time**

| Test Case ID | TC_KPI_AOEP_07 |
|---|---|
| Summary | The DMLO identifies the appropriate far-edge nodes subject to multi-faceted selection criteria defined by the Vertical Service. |
| UC number or AOEP | AOEP |
| KPI | KPI_SL_AOEP_05 |

| | |
|---|---|
| Test objective | To check if the AOEP platform is suitable to support the client selection process for FL-enabled Vertical Services. The focus is on Dynamic Criteria as defined in D3.1. |
| Pre-conditions | The vertical service should be reachable by the whole AOEP platform, including the Monitoring & Analytics and the Resource Inventory. All the components must be up and running. At least two (2) far-edge nodes must be up and running, including a Data Collection AF and a Training Node AF. Steps 1 to 4 of the test procedure have completed i.e., Data Collection AFs report on data availability, Resource Inventory retrieves OBU monitoring status. Various differentiated pre-conditions shall be established to test the ability of the AOEP to correctly select e.g.:<br>• Both Far-Edge Nodes status renders them suitable for selection (i.e., low resource utilization, availability of training data)<br>• Both Far-Edge Nodes status renders them unsuitable for selection (i.e., high resource utilization and/or unavailability of training data)<br>• Non-uniform status: one of the Far-Edge Nodes does not fulfil one of the selection criteria i.e., high resource utilization and/or unavailability of training data.<br>Alternations between these conditions will be further imposed within the test procedure. |
| Targeted result | The correct Far-Edge Node set is returned to the vertical service (Aggr Node). |
| Test procedure | 1. The Vertical Service is up and running within the context of a particular set of pre-conditions (see above).<br>2. An Aggr Node instance places the client selection request to the DMLO.<br>3. The DMLO makes the selection subject to information previously retrieved.<br>4. The Far-Edge Node set is delivered back to the Aggr Node.<br>5. The status of the system is changed (alternating the node status in agreement with the pre-condition scenarios).<br>6. Repeating steps 2 to 4. |
| Collecting data | Retrieves specific log inside each component.<br>The test will be repeated for several combinations of pre-condition and runtime scenarios, multiple times. The validation framework will extract some metrics from the logs to calculate the average, median, min and maximum value. |
| Test verdict | If the time is in the sub-second range and the selection is correct: PASS<br>If the selection is wrong: FAIL<br>If the time is not in the sub-second range: FAIL |

**Table 10, TC_KPI_AOEP_08, Far-Edge Node Activation Time**

| Test Case ID | TC_KPI_AOEP_08 |
|---|---|

| | |
|---|---|
| Summary | The DMLO activates the Training Node AF in the selected far-edge nodes. |
| UC number or AOEP | AOEP |
| KPI | KPI_SL_AOEP_06 |
| Test objective | To check if the AOEP platform is suitable to translate the client selection process for FL-enabled Vertical Services into the corresponding Training Node AF LCM actions (activation/deactivation). |
| Pre-conditions | Identical to TC_AOEP_KPI_06. |
| Targeted result | Training Node AF instances have been appropriately (de-)activated according to the client selectin criteria. Mobility related failures have been appropriately handled. |
| Test procedure | Identical to TC_AOEP_KPI_06.<br>In addition:<br>1. The Aggr Node places the final node selection request.<br>2. The DMLO forwards the request to the Policy Execution.<br>3. (Optional) A selected Far-Edge Node gets disconnected.<br>4. The Policy Execution returns the result towards the DMLO.<br>5. The result is forwarded by the DMLO to the Aggr Node.<br>6. The Aggr Node commences the new training round. |
| Collecting data | Retrieves specific log inside each component.<br>The test will be repeated for several combinations of pre-condition and runtime scenarios, multiple times. The validation framework will extract some metrics from the logs to calculate the average, median, min and maximum value. |
| Test verdict | If the time is in the 5-min range and the AF LCM events correspond to the client selection decision: PASS<br>If the AF LCM events do not correspond to the client selection decision: FAIL<br>If the time is not within the 5-min range: FAIL |

# 3. USE CASE (UC) VALIDATION

## 3.1. Introduction

The present chapter lists and describes the developed Test Cases (TC) per UC taking into account the specifics of the different deployments. The TCs have been chosen with the view that they should not only serve within the project's UC deployment validations, but to be also reutilized by the third-party experimenters that want to use the 5G-IANA platform for the implementation and deployment of their services.

Per UC, two sets of TCs are available: a) Functional tests leading to a Pass/Fail test verdict based on the observed test behaviour and b) KPI tests validating measured values e.g., Round-Trip Time Latency against the KPIs defined in D5.1 [1] chapter 2.7.

All TCs use the same table template which is described in chapter 3.2.



## 3.2. Test Case (TC) table template

Table 11 provides the template for test case descriptions.

**Table 11, TC table template**

| **Test Case ID** | **Unique identifier for each TC**<br>**Example**<br>**TC_xx_yyy_##**<br>**xx =** **FT** Functional test<br>**KPI** KPI validation test<br>**yyy =** **UCx** **x = 1 .. 7**<br>**AOEP**<br>**## =** **01 - 99** |
|---|---|
| Summary | Short high-level description of test purpose |
| UC number or AOEP | Either "UCx" (with x = 1 .. 7) or "AOEP" for platform tests |
| KPI | KPI reference from D5.1 or "n/a" for functional tests |
| Test objective | High level description of the test environment, the testing goal and the expected behaviour |
| Pre-conditions | Specific set of requirements, conditions or criteria that must be met before the test can be executed in the targeted technical testing context |
| Targeted result | Measurable result of the test for determination of the test verdict |
| Test procedure | A step-by-step description of the actions taken to achieve the test result |

| | |
|---|---|
| Collecting data | Description of the test data collection for the result determination |
| Test verdict | For functional tests in the format<br>• Result condition 1: PASS<br>• Result condition 2: FAIL<br>For KPI evaluation, a description of the comparison between KPI and measured value(s) |

## 3.3. UC TC tables

### 3.3.1. UC1 TC tables

UC1 is about the use of advanced remote driving functionalities in the open and enhanced experimentation platform developed in the 5G-IANA project. To do so, a vehicle will be wirelessly connected through 5G to a remote cockpit that includes a teleoperation platform. In the first cycle of implementation an automated guided vehicle (AGV) will be equipped with an OBU and two (front and rear) cameras to transmit the video to the edge of the 5G network. Additionally, it will carry a LiDAR to send information about its surroundings. At the 5G edge, an AI/ML algorithm will be processed and added on top of the video, providing information about the different elements located while driving on the road, such as pedestrians, cars, or traffic signals. Both LiDAR and AI detection algorithm information will be combined in a tracking algorithm to show the different objects around the AGV in a 2D representation. The second cycle will additionally include two lateral cameras. The four available cameras will generate a 360° environment that will be represented in a VR space in the cockpit.

In total 4 functional tests and 6 KPI evaluation tests have been defined for UC1 in the sub-chapters below.

#### *3.3.1.1. UC1 functional TC tables*

The integration of the different components that form the UC has been planned in an incremental manner. Up to five different steps need to be validated. The first test case is about checking the connectivity of the vehicle (OBU) to the 5G network. Once the connection is up, the edge is pinged from the OBU and from the user cockpit to check visibility in all end points. The next step is to check that the edge receives information from cameras and sensors coming from the vehicle, and the last step consists of checking this connection with the remote driving client module.

**Table 12, TC_FT_UC1_01, OBU- 5G network Connectivity Test**

| Test Case ID | TC_FT_UC1_01 |
|---|---|
| Summary | OBU can attach and register to the 5G network |
| UC number or AOEP | UC1 |
| KPI | n/a |
| Test objective | To check if the OBU can connect to the 5G Network and exchange data with the edge server. |
| Pre-conditions | OBU is powered on, SIM card is inserted, 5G network is working properly. |
| Targeted result | The OBU is connected to the 5G-IANA testbed. |
| Test procedure | 1. Connect to the OBU via console/terminal.<br>2. Check that the OBU has successfully connected to 5G network (5G modem is attached and registered to the 5G network and has obtained IP address).<br>3. Generate ICMP request from OBU to the 5G network.<br>4. Check if ICMP response has been success. |
| Collecting data | Check for PING response in console. |
| Test verdict | ICMP responses successfully received: PASS<br>ICMP response not received: FAIL |

**Table 13, TC_FT_UC1_02, OBU-Edge Connectivity Test**

| Test Case ID | TC_FT_UC1_02 |
|---|---|
| Summary | OBU to Edge Connectivity |
| UC number or AOEP | UC1 |
| KPI | n/a |
| Test objective | Check if the Edge and the ports used for each data flow are open and reachable. |
| Pre-conditions | OBU is powered on, 5G network is working properly and required ports are accessible. Visibility between OBU and edge server. |
| Targeted result | The OBU and Edge are reachable and can exchange data through the specific ports used. |
| Test procedure | 1. Connect to the OBU/Edge via console/terminal.<br>2. Generate ICMP request from OBU/Edge to Edge/OBU.<br>3. Check if ICMP response is successfully received.<br>4. Use Netcat command for each port between OBU and Edge.<br>5. Check if Netcat command response is successfully received. |
| Collecting data | Check for PING and Netcat in console. |
| Test verdict | PING and Netcat commands response successfully: PASS<br>PING and Netcat commands are not successfully: FAIL |

**Table 14, TC_FT_UC1_03, End User-Edge Connectivity Test**

| Test Case ID | TC_FT_UC1_03 |
|---|---|
| Summary | End User to Edge Connectivity |
| UC number or AOEP | UC1 |
| KPI | n/a |
| Test objective | Check if the Edge and the ports used for each data flow are open and reachable from the cockpit site. |
| Pre-conditions | The VPN is available. |
| Targeted result | The End User (client) and Edge are reachable and can exchange data through the specific ports used. |
| Test procedure | 1. Connect to the client/Edge via console/terminal.<br>2. Generate ICMP request from client/Edge to Edge/client.<br>3. Check if ICMP response is successfully received.<br>4. Use Netcat command for each port between client and Edge.<br>5. Check if Netcat command response is successfully received. |
| Collecting data | Check for PING and Netcat in console. |
| Test verdict | PING and Netcat commands response successfully: PASS<br>PING and Netcat commands are not successfully: FAIL |

**Table 15, TC_FT_UC1_04, Camera/Sensor data received**

| Test Case ID | TC_FT_UC1_04 |
|---|---|
| Summary | Edge receives Cameras & Sensors Data |
| UC number or AOEP | UC1 |
| KPI | n/a |
| Test objective | Check if the cameras and sensors data are successfully received by the edge server. |
| Pre-conditions | OBU is powered on, 5G network is working properly and required ports are accessible. Visibility between OBU and edge server. |
| Targeted result | Cameras & Sensors data is successfully received by its nApps in order to be processed in the Edge. |
| Test procedure | 1. Connect to the edge server via console/terminal.<br>2. Check the logs of each nApps. |
| Collecting data | Collect logs in edge server. |
| Test verdict | Cameras and Sensors Data are received: PASS<br>Cameras or Sensors Data are not received: FAIL |

**Table 16, TC_FT_UC1_05, End user in full control**

| Test Case ID | TC_FT_UC1_05 |
|---|---|
| Summary | End User (HMI) receives sensors, alarms and controls the vehicle |
| UC number or AOEP | UC1 |
| KPI | n/a |
| Test objective | The end user can remotely drive the vehicle using the processed information showed in the user interface. |
| Pre-conditions | All the service chain is working properly. |
| Targeted result | All the data (UL/DL) is shown on the interface and all the data flows are correctly interface (control data, sensor, data, etc.). |
| Test procedure | 1. Open the user interface and check all the functionalities (data received and commands). |
| Collecting data | Manual check. |
| Test verdict | Control the vehicle, visualize cameras, sensor data and alerts: PASS<br>Control of vehicle is not possible or cameras, sensor data and alerts are not shown: FAIL |

### *3.3.1.2. UC1 KPI TC tables*

The validation of UC1 is based on the six KPIs defined initially in D5.1 'Initial validation KPIs and metrics' where four network related KPIs (RTT latency, 5G UL/DL user data rate, E2E latency and E2E reliability) and two additional application related KPIs (AI/ML algorithm accuracy and QoE) have been defined for UC1. The following tables provide information on the steps to follow, pre-conditions, requirement and procedures associated to validate each KPI.

**Table 17, TC_KPI_UC1_01, RTT**

| Test Case ID | TC_KPI_UC1_01 |
|---|---|
| Summary | 5G Round Trip Time (RTT): RTT between UE and edge server |
| UC number or AOEP | UC1 |
| KPI | KPI_NL_UC1_01 |
| Test objective | UC1 can be executed safely if the average RTT between UE and edge server does not exceed the maximum value. |
| Pre-conditions | 5G network is operational. Visibility between OBU and edge server. |
| Targeted result | RTT <= 20 ms |
| Test procedure | 1. Check UE connectivity to 5G network (IP address assigned).<br>2. PING from the UE to the edge server. |
| Collecting data | Collect logs in the UE. |

| | |
|---|---|
| Test verdict | Compare results obtained through the test to targeted results value. |

**Table 18, TC_KPI_UC1_02, 5G User Data Rate**

| Test Case ID | TC_KPI_UC1_02 |
|---|---|
| Summary | 5G User Data Rate: UL/DL Throughput rate between the UE and the edge server |
| UC number or AOEP | UC1 |
| KPI | KPI_NL_UC7_02 |
| Test objective | Minimum bandwidth which is required to transmit each kind of data from the UE (vehicle) and the edge server in UL/DL direction. |
| Pre-conditions | 5G network is operational. Visibility between OBU and edge server.<br>Specific ports for each type of data should be accessible. |
| Targeted result | Total UL > 24 Mbps<br>Video from the AGV in UL direction:<br>- Front camera: UL > 10 Mbps<br>- Back camera: UL > 10 Mbps<br>Laser information: UL > 4 Mbps<br>Total DL > 50 kbps<br>AGV Control Data: DL > 50 kbps |
| Test procedure | 1. Check UE connectivity to 5G network (IP address assigned).<br>2. Check connectivity to edge server through PING.<br>3. Establish TCP/UDP Clients & Servers (OBU and Edge for UL/DL data).<br>4. iPerf between each node. |
| Collecting data | Collect logs in the UE. |
| Test verdict | Compare results obtained through the test to targeted results value. |

**Table 19, TC_KPI_UC1_03, E2E Latency**

| Test Case ID | TC_KPI_UC1_03 |
|---|---|
| Summary | E2E Latency: Maximum accepted latency across the entire service chain, including the application |
| UC number or AOEP | UC1 |
| KPI | KPI_SL_UC1_01 |
| Test objective | UC1 Requires low latency on the entire service chain (including the application) to guarantee proper execution of the vehicle remote driving. All nApps of the UC are correctly running. |

| | |
|---|---|
| Pre-conditions | 5G network is operational. Visibility between OBU and edge server. HMI connectivity to edge server. Specific ports for each type of data should be accessible. |
| Targeted result | UL Video < 150 ms<br>UL Laser Information < 50 ms<br>UL/DL AGV Control Data < 50 ms |
| Test procedure | 1. It will be measured by comparing two timestamps: the first input provided in the controller against the exact moment where the AGV is starting to move (by using a photodiode and laser system). |
| Collecting data | Collect logs in the OBU and the Edge. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 20, TC_KPI_UC1_04, E2E Reliability**

| **Test Case ID** | TC_KPI_UC1_04 |
|---|---|
| Summary | E2E Reliability: Percentage of correctly received packets over the total packets transmitted in the complete service chain |
| UC number or AOEP | UC1 |
| KPI | KPI_SL_UC1_02 |
| Test objective | To properly operate the remote driving and to safeguard the proper execution of it, avoiding potential accidents, a reliable connection is needed. The user is controlling the vehicle remotely, so it is key to keep the video and specially the control available. |
| Pre-conditions | 5G network is operational. Visibility between OBU and edge server. HMI connectivity to edge server. Specific ports for each type of data should be accessible. All nApps are correctly running. |
| Targeted result | UL Video > 99.9%<br>UL Laser Information > 99.999%<br>AGV Control Data > 99.999% |
| Test procedure | 1. Execute PING for a consistent time with a packet size coherent with typical nApp communication message (as to stress network fragmentation) to measure the absolute packet loss. |
| Collecting data | Collect logs in the OBU and the Edge. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 21, TC_KPI_UC1_05, AI Algorithm Accuracy**

| **Test Case ID** | TC_KPI_UC1_05 |
|---|---|

| | |
|---|---|
| Summary | AI Algorithm Accuracy: Accuracy of correctly detected elements located while driving on the road |
| UC number or AOEP | UC1 |
| KPI | KPI_SL_UC7_03 |
| Test objective | A certain level of accuracy in object detection is needed to reliably inform the driver about obstacles/signals on the road and/or stop the vehicle when a potential accident may occur. |
| Pre-conditions | Requirements:<br>- User Speed < 50 km/h<br>- Objects detected > 20 objects/frame<br>Range < 10 m |
| Targeted result | Accuracy > 0.7 |
| Test procedure | 1. The AI algorithm automatically estimates the accuracy of the detection which is stamped around the object on the current video frame and stored in a log. |
| Collecting data | Collect logs in the Edge. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 22, TC_KPI_UC1_06, QoE**

| Test Case ID | TC_KPI_UC1_06 |
|---|---|
| Summary | Quality of Experience: General acceptability of the service, as subjectively perceived by the end user, covering the full effects of the end-to-end system |
| UC number or AOEP | UC1 |
| KPI | KPI_SL_UC1_04 |
| Test objective | The nApp will need to provide a high QoE to achieve high service reliability and a good user experience to ensure safety remote driving. |
| Pre-conditions | All the service chain must function correctly. |
| Targeted result | MOS > 4.3 |
| Test procedure | 1. Measurement method MOS (Mean Opinion Score). Users rate the service quality through a form with different questions related to. They score for each feature from 5 to 1, where 5 is the best quality and 1 is the worst quality. |
| Collecting data | Form for each user on HMI. |
| Test verdict | Quality can be classified as Bad [0 – 1], Poor [1 – 2], Fair [2 – 3], Good [3 – 4] and Excellent [4 – 5]. Compare results gained through the test to targeted results value. |

### 3.3.2. UC2 TC tables

UC2 is intended to demonstrate the potential of the 5G-IANA platform by introducing a manoeuvre coordination service able to handle realistic traffic scenarios at intersections. This service, called MCAD (Manoeuvre Coordination for Autonomous Driving), will generate paths and priorities to vehicles arriving at its target intersection, which will then be translated to manoeuvre coordination messages that will command autonomous vehicles and give instructions to human-driven ones connected to the platform.

Two scenarios will be considered. The first one will consist of an autonomous vehicle and a human-driven vehicle, both with OBUs able to connect to the 5G-IANA platform, which will arrive at an intersection present at the test site. They will subscribe to the MCAD service, which will give instructions to both vehicles, allowing for safe and efficient passage.

The second scenario will simulate a complex traffic situation by adding virtual vehicles on the CARLA simulator. These simulated vehicles will be autonomous and have virtual OBUs which present the same characteristics as their physical counterparts, therefore using the MCAD service in the same way. In this scenario, all vehicles (the two physical ones and the virtual ones traveling on a digital twin of the test site) will approach the intersection and will again be guided safely and efficiently.

In total 5 functional tests and 5 KPI evaluation tests have been defined for UC2 in the sub-chapters below.

#### *3.3.2.1. UC2 functional TC tables*

Functional tests for UC2 are structured in an incremental manner which follows the logical flow of the UC itself. Initial tests regard the most basic and crucial of functions, which is to have OBUs (both physical and virtual) connect to the platform. Once that is asserted, tests on the MCAD service can be done to check if it can assign feasible paths. Final tests are then designed to confirm that the entire E2E chain is functioning properly by commandeering the autonomous vehicles and giving instructions to the human-driven ones.

**Table 23, TC_FT_UC2_01, OBU Connectivity Test**

| Test Case ID | TC_FT_UC2_01 |
|---|---|
| Summary | OBUs can attach and register to the 5G network |
| UC number or AOEP | UC2 |
| KPI | n/a |

| | |
|---|---|
| Test objective | Vehicles, together with the 5G-IANA platform, take centre stage in this UC, so for all of them to work together it is of outmost importance to confirm that connection between the vehicle OBUs and the 5G network is properly established. |
| Pre-conditions | OBUs are powered on and operational, edge server operational, 5G network is available. |
| Targeted result | OBUs are connected to the 5G-IANA testbed, with the possibility to properly exchange messages. |
| Test procedure | 1. Connect to OBU via LiNKS management console.<br>2. Check OBU has successfully connected to 5G network (5G modem is attached and registered to the 5G network and has obtained IP address).<br>3. Generate ICMP request from OBU to qMON Ref Server deployed at the Edge.<br>4. Check if ICMP response has been successfully received. |
| Collecting data | Check for ICMP response in management console. |
| Test verdict | ICMP responses successfully received: PASS<br>ICMP response not received: FAIL |

**Table 24, TC_FT_UC2_02, vOBU Connectivity Test**

| Test Case ID | TC_FT_UC2_02 |
|---|---|
| Summary | Simulated Vehicles are connected via vOBUs to the network |
| UC number or AOEP | UC2 |
| KPI | n/a |
| Test objective | For the second UC2 scenario, a higher complexity situation is achieved by means of the inclusion of simulated vehicles. These vehicles should behave as their real-world counterparts, therefore the vOBUs must also be connected to the network. |
| Pre-conditions | CARLA simulator environment and plugin up and running, vehicle and vOBU instances running. |
| Targeted result | vOBUs connected to the network, with the possibility to exchange messages. |
| Test procedure | 1. Check CARLA environment is running, confirm number of virtual vehicles.<br>2. Confirm the corresponding vOBUs are operational from the CARLA plugin.<br>3. Check that all vOBUs are sending/receiving messages. |
| Collecting data | Log exchanged messages between vOBUs and network from the CARLA plugin. |
| Test verdict | All virtual vehicles have OBUs sending/receiving messages: PASS<br>OBUs/messages missing: FAIL |

**Table 25, TC_FT_UC2_03, MCAD Path Generation Test**

| Test Case ID | TC_FT_UC2_03 |
|---|---|
| Summary | MCAD assigns feasible paths to all vehicles |
| UC number or AOEP | UC2 |
| KPI | n/a |
| Test objective | MCAD is able to achieve its goal of managing traffic in a safe and efficient manner by planning guidance for all vehicles. |
| Pre-conditions | OBU/vOBU connection established for all vehicles. |
| Targeted result | Each vehicle present in the scenario is assigned a feasible path. |
| Test procedure | 1. Read vehicle position data from the exchanged messages.<br>2. Monitor MCAD assigned paths. |
| Collecting data | Visual check on created paths and number of actors. |
| Test verdict | All vehicles are assigned feasible paths: PASS<br>Not all vehicles have paths/ presence of unfeasible paths: FAIL |

**Table 26, TC_FT_UC2_04, Autonomous Vehicle Command Test**

| Test Case ID | TC_FT_UC2_04 |
|---|---|
| Summary | AV/Simulated vehicles able to move based on received MCAD directives |
| UC number or AOEP | UC2 |
| KPI | n/a |
| Test objective | Confirm that MCAD can actually manage self-driving vehicles by commandeering them. |
| Pre-conditions | OBU/vOBU connection established, AV/simulated vehicles in autonomous mode. |
| Targeted result | Vehicles issue throttle, brake and steering commands based on MCAD instructions. |
| Test procedure | 1. Check vehicles are in autonomous mode<br>2. Confirm messages from MCAD are being received<br>3. Assert that vehicle issues commands according to received messages |
| Collecting data | Manual cross-check between MCAD messages and longitudinal/lateral vehicle commands. |
| Test verdict | Commands match received messages: PASS<br>Commands not matching received messages: FAIL |

**Table 27, TC_FT_UC2_05, Driver Instructions Test**

| Test Case ID | TC_FT_UC2_05 |
|---|---|

| | |
|---|---|
| Summary | HMI displays suggested actions to driver based on MCAD directives |
| UC number or AOEP | UC2 |
| KPI | n/a |
| Test objective | In the case of human-driven vehicles, instructions from MCAD must be clearly shown to the driver so the manoeuvre coordination is successful. |
| Pre-conditions | OBU connection established, HMI operational and driver ready to respond. |
| Targeted result | Driver can clearly read HMI instructions and may act accordingly. |
| Test procedure | 1. Check HMI is ready to display MCAD directives<br>2. Confirm messages from MCAD are being received<br>3. Assert instructions are being displayed on HMI |
| Collecting data | Visual check on HMI. |
| Test verdict | Instructions clearly visible on HMI: pass<br>Instructions not visible/ unclear: FAIL |

#### *3.3.2.2. UC2 KPI TC tables*

KPI tests for UC2 focus on obtaining relevant information on the performance of both the network and services involved in this test case, by monitoring response and times, reliability and availability. These KPIs are of outmost importance to this UC, as manoeuvre coordination is a safety relevant application, so high speed and reliability targets must be achieved.

**Table 28, TC_KPI_UC2_01, RTT**

| Test Case ID | TC_KPI_UC2_01 |
|---|---|
| Summary | 5G Round Trip Time (RTT): RTT between UE and edge server |
| UC number or AOEP | UC2 |
| KPI | KPI_NL_UC2_01 |
| Test objective | Low latency on the access segment is required for UC2 to guarantee interaction of the real-to-life vehicles with the manoeuvre coordination service and with simulated vehicles. |
| Pre-conditions | OBU and edge server connected to the network, all operational. |
| Targeted result | Average RTT <= 20 ms |
| Test procedure | 1. Execute ping for some time to measure the average round trip time. |
| Collecting data | Test logs will be created upon receiving ping results. |
| Test verdict | Comparison between test results and target value present in this table. |

**Table 29, TC_KPI_UC2_02, E2E Reliability**

| Test Case ID | TC_KPI_UC2_02 |
|---|---|
| Summary | E2E Reliability: Minimum reliability required to assure the proper service operation (e.g., safe driving) |
| UC number or AOEP | UC2 |
| KPI | KPI_NL_UC2_02 |
| Test objective | High reliability is required to properly operate the manoeuvre coordination service and to safeguard the proper execution of manoeuvres on behalf of each involved vehicle. |
| Pre-conditions | OBU and edge server connected to the network, all operational. |
| Targeted result | Packet Loss Rate< $10^{-4}$ |
| Test procedure | 1. Execute ping for a consistent time with a packet size coherent with typical nApp communication messages (as to stress network fragmentation) to measure the absolute packet loss. |
| Collecting data | Test logs will be created upon receiving ping results. |
| Test verdict | Comparison between test results and target value present in this table. |

**Table 30, TC_KPI_UC2_03, E2E Latency**

| Test Case ID | TC_KPI_UC2_03 |
|---|---|
| Summary | E2E Latency: The maximum accepted latency across the entire service chain |
| UC number or AOEP | UC2 |
| KPI | KPI_SL_UC2_01 |
| Test objective | UC2 requires low latency on the entire service chain to guarantee proper execution of the vehicle coordination. |
| Pre-conditions | OBU and edge server connected to the network, all operational.<br>WireShark/ntopng up and running, ready to monitor. |
| Targeted result | Average time for request/response transactions < 500ms |
| Test procedure | 1. RTT measurements based on Wireshark/ntopng observation of protocol packet timestamps. |
| Collecting data | WireShark/ntopng logs. |
| Test verdict | Comparison between test results and target value present in this table. |

**Table 31, TC_KPI_UC2_04, Service Availability**

| Test Case ID | TC_KPI_UC2_04 |
|---|---|

| | |
|---|---|
| Summary | Service Availability: Service availability, the percentage of time the service is offered properly |
| UC number or AOEP | UC2 |
| KPI | KPI_SL_UC2_02 |
| Test objective | The nApp must be considered always in the UC2 context as loss of service availability is very dangerous both for vehicles during manoeuvres and vehicles adding to the manoeuvres. Losing the ability to properly complete a manoeuvre or try to join the manoeuvre coordination without success exposes involved vehicles to high risk and produces traffic paralysis. |
| Pre-conditions | OBU and edge server connected to the network, all operational. Connection logging available. |
| Targeted result | Service availability >= 99.999% |
| Test procedure | 1. Measure number of successful requests over the total number of requests on a considerable timespan, which starts upon arrival of the first vehicle and ends when the intersection is clear (or the MCAD service is shut down). |
| Collecting data | Client-side log postprocessing. |
| Test verdict | Comparison between test results and target value present in this table. |

**Table 32, TC_KPI_UC2_05, Service Deployment Time**

| Test Case ID | TC_KPI_UC2_05 |
|---|---|
| Summary | Service Deployment Time: Time for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.) |
| UC number or AOEP | UC2 |
| KPI | KPI_SL_UC2_03 |
| Test objective | UC2 deeply relies on a prompt service access that resides in a fast setup of all the application's communications to/from the OBUs |
| Pre-conditions | OBU and edge server connected to the network, all operational. Server logging available. KPI_NL_UC2_01, KPI_NL_UC2_02 and KPI_SL_UC2_01 must also be measurable. |
| Targeted result | Service deployment time <= 5s |
| Test procedure | 1. Log timestamp when MCAD detects the OBU<br>2. Measure time taken between step 1 and the successful exchange of information to/from OBU, with KPI_NL_UC2_01, KPI_NL_UC2_02 and KPI_SL_UC2_01 inside their target ranges. |
| Collecting data | Logging from nApp. |

| | |
|---|---|
| Test verdict | Comparison between test results and target values present in this table. |

### 3.3.3. UC3 TC tables

UC3 (UC3-VBT) belongs to the infotainment use case category. It will demonstrate a real-time sightseeing tour in the city of Ulm area based on the combination of virtual reality (VR) and high resolution 360° video. The scenario of UC3 involves two users joining a tour guide in a VR environment offered by the nApp simulating a double-decker open top bus commonly used in such tours. Through the nApp the users will be able to speak, listen and gesture with one another and the tour guide. Additional information concerning the sights during the tour will be available through GPS-driven landmark indicators.

In total 6 functional tests and 9 KPI evaluation tests have been defined for UC3 in the sub-chapters below.

#### *3.3.3.1. UC3 functional TC tables*

Similar to the rest of the 5G-IANA UCs, UC3 functional tests were mostly designed to ensure end-to-end connectivity for the functionalities required to fully demonstrate this use case. Tests start examining the connectivity of components found in the Edge, continue with connectivity tests to the Central Cloud and finally the E2E chain is examined. Additionally, a test is performed to ensure that the end users can correctly communicate with one another through the VR components of the nApp.

**Table 33, TC_FT_UC3_01, OBU connectivity**

| Test Case ID | TC_FT_UC3_01 |
|---|---|
| Summary | OBU can attach and register to the 5G network |
| UC number or AOEP | UC3 |
| KPI | n/a |
| Test objective | The OBU is a key HW components required for UC3 as it provides connectivity to the network. This test checks if it is successfully connected to the 5G network of 5G-IANA testbed(s). |
| Pre-conditions | OBU is powered on and operational, SIM card is inserted – to be confirmed by accessing dedicated LiNKS management console which is not connected over 5G-IANA testbed 5G network. |
| Targeted result | The OBU are connected to the 5G-IANA testbed of the 5G network and can exchange data with the edge server. |
| Test procedure | 1. Connect to the OBU via LiNKS management console.<br>2. Check that the OBU has successfully connected to 5G network (5G |

| | |
|---|---|
| | modem is attached and registered to the 5G network and has obtained IP address).<br>3. Generate ICMP request from OBU to qMON Ref Server deployed in the edge server.<br>4. Check if ICMP response has been successfully received. |
| Collecting data | Check for ICMP response in management console. |
| Test verdict | ICMP responses successfully received: PASS<br>ICMP response not received: FAIL |

**Table 34, TC_FT_UC3_02, Edge PC to OBU connectivity**

| Test Case ID | TC_FT_UC3_02 |
|---|---|
| Summary | Check Edge PC to OBU Connectivity |
| UC number or AOEP | UC3 |
| KPI | n/a |
| Test objective | Confirm the connectivity between the Edge PC and the OBU. |
| Pre-conditions | n/a |
| Targeted result | Edge PC connected to the OBU. |
| Test procedure | 1. Connect from the Edge PC to the OBU via LiNKS management console. |
| Collecting data | Manual check. |
| Test verdict | Edge PC connected to the OBU: PASS<br>Edge PC not connected to the OBU: FAIL |

**Table 35, TC_FT_UC3_03, 360º camera to Edge PC connectivity**

| Test Case ID | TC_FT_UC3_03 |
|---|---|
| Summary | 360º Camera is operational |
| UC number or AOEP | UC3 |
| KPI | n/a |
| Test objective | Confirm the connectivity between the Edge PC and the 360° camera. |
| Pre-conditions | Camera is physically connected to a laptop PC that is connected to the OBU. nApp component (Streaming) that enables collecting video is active. |
| Targeted result | nApp component (Streaming) is receiving video stream from the camera. |
| Test procedure | 1. Check the camera is physically connected to the laptop<br>2. Check that the laptop PC is connected to the OBU.<br>3. Check the nApp component (streaming) of the laptop PC is receiving video stream from the camera. |
| Collecting data | Manual check. |
| Test verdict | Video stream received: PASS |

| | |
|---|---|
| | Video stream not received: FAIL |

**Table 36, TC_FT_UC3_04, Edge PC to Central Cloud Connectivity**

| Test Case ID | TC_FT_UC3_04 |
|---|---|
| Summary | Check Edge PC to Central Cloud Connectivity |
| UC number or AOEP | UC3 |
| KPI | n/a |
| Test objective | Confirm the connectivity between the Edge PC and the Central cloud (via the edge server). |
| Pre-conditions | All previous tests (TC_FT_UC3_01-03). |
| Targeted result | nApp component (logging) is receiving a log from another nApp Component (network monitoring). |
| Test procedure | 1. Sent a log of the "Active Network Monitoring Module" nApp component located in the Edge PC to the "UC-Specific Log Reporting Service" nApp component located in the central cloud.<br>2. Check that the log was successfully received and stored. |
| Collecting data | Manual check. |
| Test verdict | Log was successfully received and stored: PASS<br>Log was successfully received and stored: FAIL |

**Table 37, TC_FT_UC3_05, Ensure that End User receives data**

| Test Case ID | TC_FT_UC3_05 |
|---|---|
| Summary | End user's UE receives video stream and Spatial Data |
| UC number or AOEP | UC3 |
| KPI | n/a |
| Test objective | To check VR user can access content provided by the nApp. |
| Pre-conditions | All previous tests (TC_FT_UC3_01-04). |
| Targeted result | User is able to access the video content provided by the service. |
| Test procedure | 1. Users connect to the VR application and receive video and spatial data. |
| Collecting data | Manual check for data and video-stream. |
| Test verdict | Data and video-stream are available as expected: PASS<br>Data or video-stream not available (or not updated regularly, video is frozen, etc.): FAIL |

**Table 38, TC_FT_UC3_06, Ensure user-to-user communication inside the nApp**

| Test Case ID | TC_FT_UC3_06 |
|---|---|
| Summary | End users can properly communicate via the VR application |
| UC number or AOEP | UC3 |
| KPI | n/a |
| Test objective | To check VR users can properly communicate via the VR application via speaking, gesturing and receiving spatialized audio data. |
| Pre-conditions | All previous tests (TC_FT_UC3_01-05). |
| Targeted result | User is able to access the content provided by the service. |
| Test procedure | 1. Users connect to the VR application and speak to each other Users can gesture and use hand signs. |
| Collecting data | Manual check for data and video-stream. |
| Test verdict | Users can properly communicate using signs and speech via the VR application: PASS<br>Users cannot communicate via the VR application: FAIL |

#### *3.3.3.2. UC3 KPI TC tables*

The KPIs chosen for evaluation in UC3 have three primary targets: Initially, to ensure that the network can provide the resources required by the nApp to stream, without interruptions, a near-real time high quality 360° video. Then, to ensure that the end-users can interact through the VR application in real-time and finally to test the scalability of the nApp.

**Table 39, TC_KPI_UC3_01, 5G Round Trip Time**

| Test Case ID | TC_KPI_UC3_01 |
|---|---|
| Summary | 5G Round Trip Time (RTT): RTT between UE and local edge server |
| UC number or AOEP | UC3 |
| KPI | KPI_NL_UC3_01 |
| Test objective | To measure/test and evaluate average RTT between the UE (an edge PC) and the local edge server. Low latency is required in the context of UC3 to achieve high fidelity in matching the avatars responses with the virtual tour 360º video stream. The average RTT represents a baseline for the minimum transport latency, which is one component of the E2E latency. |
| Pre-conditions | 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server. The OBU will handle the connection. |
| Targeted result | Average RTT <= 20 ms |
| Test procedure | 1. Check that UE is properly connected to the 5G network (IP connectivity established). |

| | |
|---|---|
| | 2. Ping from the Far Edge PC to the edge server. |
| Collecting data | Collect logs in the edge PC. A nApp component was created to log the measurements for this KPI. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 40, TC_KPI_UC3_02, User Data Rate**

| **Test Case ID** | TC_KPI_UC3_02 |
|---|---|
| Summary | User Data Rate |
| UC number or AOEP | UC3 |
| KPI | KPI_NL_UC3_02 |
| Test objective | Measure and evaluate the bit rate used between Far Edge PC (UE) and edge server. In UC3 a) the uplink throughput rate should be enough to support a constant data flow for 4k video, otherwise chopping could be experienced in the receiver's end. And b) the throughput rate should be enough to cover the exchange of high priority control data. |
| Pre-conditions | 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server. The OBU will handle the connection. |
| Targeted result | Video stream: uplink throughput >= 8Mbps (minimum), 16 Mbps preferred<br>Control data:<br>- uplink throughput >=100 kbps<br>- downlink throughput >= 100kbps |
| Test procedure | 1. Check that the Edge PC is properly connected to the 5G network (IP connectivity established).<br>2. Get User data rate from the Video Encoder AF. Additionally, run iPerf tool to verify the values. |
| Collecting data | Encoder logs and iPerf logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 41, TC_KPI_UC3_03, E2E Reliability**

| **Test Case ID** | TC_KPI_UC3_03 |
|---|---|
| Summary | E2E Reliability |
| UC number or AOEP | UC3 |
| KPI | KPI_NL_UC3_03 |
| Test objective | Measure and calculate the probability of successfully delivered packets from the Far Edge PC to the edge server within a target latency threshold |

| | |
|---|---|
| | i.e., the packets are not either erroneous, lost, or arrive too late. UC3 requires near-real time response rates to match the avatars responses with the virtual tour 360º video stream, and to achieve an engaging and responsive experience: Packet error rate causes dropped packets which can result in lagging of the video stream. |
| Pre-conditions | 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server. The OBU will handle the connection. |
| Targeted result | Reliability >= 99.99% (packet error rate < $10^{-4}$) within a latency threshold of 20 ms (per KPI_NL_UC3_01). |
| Test procedure | 1. Check that the Edge PC is properly connected to the 5G network (IP connectivity established).<br>2. Run Wireshark tool. |
| Collecting data | Wireshark logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 42, TC_KPI_UC3_04, Connectivity interruption time**

| Test Case ID | TC_KPI_UC3_04 |
|---|---|
| Summary | Connectivity interruption time |
| UC number or AOEP | UC3 |
| KPI | KPI_NL_UC3_04 |
| Test objective | Evaluate the frequency with which a user terminal cannot exchange user plane packets with any base station for 6 seconds or longer. |
| Pre-conditions | 1. 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server.<br>2. A UC3 nApp component called 'Active Network Monitoring Module' is active both in the edge Pc and the edge server. |
| Targeted result | Mobility interruption time < 0.01% during the execution of the entire UC3 scenario i.e., the completion of a Bus Tour in the city of Ulm. For example, a tour of 60 minutes is comprised of 600 intervals each with a duration of 6s. The 0.01% of these intervals i.e., the maximum number of intervals to achieve the targeted result, is 6 intervals. |
| Test procedure | 1. Check that the Edge PC is properly connected to the 5G network (IP connectivity established).<br>2. Once the execution of the UC trial starts, the nApp component called 'Active Network Monitoring Module' in the Edge PC will automatically start contacting a second instance of the same nApp component situated in the edge server and log each time such a contact was attempted and if it was successful or not. |
| Collecting data | An nApp component was created to log the measurements for this KPI. |

| | |
|---|---|
| Test verdict | A buffering mechanism will be employed to maintain video fidelity to the end users, even in no network service availability scenarios. Network disconnection exceeding the duration of 6s when in mobile network coverage, will inhibit the real time aspects of the virtual tour. To evaluate the KPI the Number of network disconnection occurrences between the OBU and the network that exceed 6s will be measured. Compare results gained through the test to targeted results value. |

**Table 43, TC_KPI_UC3_05, E2E Latency**

| Test Case ID | TC_KPI_UC3_05 |
|---|---|
| Summary | E2E Latency |
| UC number or AOEP | UC3 |
| KPI | KPI_SL_UC3_01 |
| Test objective | Evaluate the duration required to send data between two points of the service chain. A latency should not exceed a threshold to maintain the communication between the users, who via their avatars will be able to gesture, speak and listen to one another. |
| Pre-conditions | 1. 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server.<br>2. Edge Server is connected to the Central Cloud.<br>3. End Users are connected to the relevant nApp component (VR application). |
| Targeted result | UL video latency <= 200 ms |
| Test procedure | 1. Check that the Edge PC is properly connected to the 5G network (IP connectivity established).<br>2. Check that the video stream can reach the End-Users.<br>3. Perform measurements via iperf between the Far Edge PC and the VR application server, and between the VR user application and the VR server components of the UC. |
| Collecting data | Collect logs in the edge PC. An nApp component was created to log the measurements for this KPI. |
| Test verdict | Compare results gained through the test to targeted results value. |



**Table 44, TC_KPI_UC3_06, Service Availability**

| Test Case ID | TC_KPI_UC3_06 |
|---|---|
| Summary | Service Availability |
| UC number or AOEP | UC3 |
| KPI | KPI_SL_UC3_02 |

| | |
|---|---|
| Test objective | The percentage of time the service is offered properly: the nApp has to be available and provide continuous sessions after the user is successfully connected. |
| Pre-conditions | 1. 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server.<br>2. Edge Server is connected to the Central Cloud.<br>3. End Users are connected to the relevant nApp component (VR application). |
| Targeted result | Service availability >= 99.999%. |
| Test procedure | 1. Check that the Edge PC is properly connected to the 5G network (IP connectivity established).<br>2. Check that the video stream can reach the End-Users.<br>3. Perform availability checks for all interconnected components of the UC. |
| Collecting data | The edge PC will make perform the availability calls. An nApp component was created to and log the measurements for this KPI. |
| Test verdict | Compare results gained through the test to targeted results value. E2E availability will be monitored between each interconnected component. When a component of the service is not available, while a trial is taking place, then it will be assumed that the service is not available. |

**Table 45, TC_KPI_UC3_07, Application Jitter**

| Test Case ID | TC_KPI_UC3_07 |
|---|---|
| Summary | Application Jitter |
| UC number or AOEP | UC3 |
| KPI | KPI_SL_UC3_04 |
| Test objective | Measure jitter i.e., the standard deviation of the end-to-end latency for the communications between specific components of the vertical service. Evaluate that low jitter values are maintained to ensure stability and reliability of the communication channels. |
| Pre-conditions | 1. 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server.<br>2. Edge Server is connected to the Central Cloud.<br>3. End Users are connected to the relevant nApp component (VR application). |
| Targeted result | Mean Jitter < 30 ms per user for the duration of a trial/demonstration. |
| Test procedure | 1. Check that the VR App and the VR server are connected i.e., user can log into the VR environment.<br>2. Log jitter for the remainder of the trial. |
| Collecting data | VR synchronization protocol will provide jitter measurements and the VR server nApp component will log them. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 46, TC_KPI_UC3_08, Maximum number of simultaneous Users**

| Test Case ID | TC_KPI_UC3_08 |
|---|---|
| Summary | Maximum number of simultaneous Users |
| UC number or AOEP | UC3 |
| KPI | KPI_SL_UC3_05 |
| Test objective | Evaluate the maximum number of users that can be accommodated by the service per area for predefined levels of service. |
| Pre-conditions | 1. 5G network is operational, and an Edge PC is connected via the 5G network to the local edge server.<br>2. Edge Server is connected to the Central Cloud.<br>3. End Users are connected to the relevant nApp component (VR application). |
| Targeted result | At least number of users > 10 is expected. |
| Test procedure | 1. Artificial end users (bots) will be incrementally added to the app until the point where the requirements for NL and SL KPIs KPI_NL_UC3_03, KPI_SL_UC3_01, KPI_SL_UC3_02, KPI_SL_UC3_04 (as measured by relevant tests) are not met. |
| Collecting data | See tests for NL and SL KPIs KPI_NL_UC3_03, KPI_SL_UC3_01, KPI_SL_UC3_02, KPI_SL_UC3_04. |
| Test verdict | At least 10 users were accommodated by the service: PASS<br>Less than 10 users were accommodated by the service: FAIL |

**Table 47, TC_KPI_UC3_09, Service deployment time**

| Test Case ID | TC_KPI_UC3_09 |
|---|---|
| Summary | Service deployment time |
| UC number or AOEP | UC3 |
| KPI | KPI_SL_UC3_06 |
| Test objective | To measure/test and evaluate service deployment time, the duration needed for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.). |
| Pre-conditions | AOEP platform is operational, testbed is fully operational, requested UEs/RSUs/OBUs are connected to the 5G network. Test scripts (deployment and scale-out) are prepared. |
| Targeted result | Initial service deployment time <= 3 min<br>Service scale-out <= 1 min |

| | |
|---|---|
| Test procedure | 1. Check all pre-conditions are met.<br>2. Start service deployment script.<br>3. Start service scale-out script. |
| Collecting data | AOEP logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

### 3.3.4. UC4 TC tables

UC4 is an AR streaming application through 5G RAN and edge server elements as a future mobility infotainment application. The developed nApp will use both edge computing and AR technology to offload the computing power needed to display high-quality 3D objects. The nApp consists of both an AR engine at the terminal side, and a protocol streaming application, where the 3D objects are being streamed down to AR-enabled devices. The 3D-objects streaming will be provided to the navigation environment by using ARCore Geospatial API and the Google places. The AR streaming application will inform the users with the Google places information in real time without the need of searching for them. The nApp will take into account different elements of the AR streaming settings of the UE such as location, context, speed and throughput. The intelligent nApp will exploit the 5G edge server existence and capabilities, bringing the services of the application closer to the user in order to satisfy the need for QoE. The QoE will be delivering a high-quality AR content including virtual 3D objects in low latency taking into account the consideration the coverage of the 5G network in Ulm combined with the user's data rate so it will adjust to the system requirements. The fAR content streaming nApp requires a set of KPIs that is explained in detail below.

In total 2 functional tests and 3 KPI evaluation tests have been defined for UC4 in the sub-chapters below.

#### *3.3.4.1. UC4 functional TC tables*

The following test cases are relevant to connectivity that will guarantee the proof of concept of UC4. In particular, the connectivity of the UE to the 5G RAN and edge server elements of the 5G-IANA infrastructure will be validated through the first two test cases. The third one will validate the overall UC4 service availability testing as actual access to the nApp.

**Table 48, TC_FT_UC4_01, UE – Edge Connectivity Test**

| Test Case ID | TC_FT_UC4_01 |
|---|---|
| Summary | Checking the connectivity status of UE to the Edge |
| UC number or AOEP | UC4 |

| | |
|---|---|
| KPI | n/a |
| Test objective | Confirm the connectivity between the smartphone and the edge server connectivity in Ulm. |
| Pre-conditions | n/a |
| Targeted result | Smartphone connected to the edge Server. |
| Test procedure | Connect the smartphone to the Nokia 5G pilot network in Ulm through the edge server. |
| Collecting data | Through mobile end device and the edge server. |
| Test verdict | Smartphone connected to the edge server: PASS<br>Smartphone not connected to the edge server: FAIL |

**Table 49, TC_FT_UC4_02, Streaming functional**

| Test Case ID | TC_FT_UC4_02 |
|---|---|
| Summary | UE receives AR streaming content |
| UC number or AOEP | UC4 |
| KPI | n/a |
| Test objective | To check AR user application that can receive, and access content provided by the nApp. |
| Pre-conditions | All previous tests (TC_FT_UC4_01-02). |
| Targeted result | User is able to access the AR content provided by the nApp. |
| Test procedure | Mobile users connect to the AR application and receive AR 3D objects. |
| Collecting data | Through the mobile phone device. |
| Test verdict | AR 3D objects streaming are available as expected: PASS<br>3D objects are not available and not updated regularly, AR streaming is frozen: FAIL |

### *3.3.4.2. UC4 KPI TC tables*

The following KPIs are relevant to connectivity that will prove the concept of UC4 i.e., the low latency AR streaming application. In particular, the RTT among the 5G RAN and edge server elements to the UE will be tested on the 5G-IANA infrastructure. These are considered the first two KPIs. The third KPI will measure the overall UC4 service availability as an end-to-end service availability of the nApp to the mobile users.

**Table 50, TC_KPI_UC4_01, Latency**

| Test Case ID | TC_KPI_UC4_01 |
|---|---|

| | |
|---|---|
| Summary | This KPI is to measure the average latency between the UE and the edge server, where the UC4 is running through. |
| UC number or AOEP | KPI_NL_UC4_01 |
| KPI | RTT between UE and local edge server. |
| Test objective | To measure/test and evaluate average RTT between the UE (mobile device) and the local edge server. Low latency is required in the context of UC4 to achieve a responsive AR content delivery. The RTT represents a baseline for the minimum transport latency, which is one component of the E2E latency. |
| Pre-conditions | 5G network is operational, and a mobile device is connected via the 5G network to the local edge server. The 5G RAN will manage this type of connection. |
| Targeted result | Average RTT <= 20 ms |
| Test procedure | 1. Check that UE is properly connected to the 5G network (IP connectivity established).<br>2. Ping from the mobile user to the edge server. |
| Collecting data | Collect logs in the mobile user device and the edge server. |
| Test verdict | Compare results gained through the test to targeted results value. |



**Table 51, TC_KPI_UC4_02, User Data Rate**

| Test Case ID | TC_KPI_UC3_02 |
|---|---|
| Summary | User Data Rate |
| UC number or AOEP | UC3 |
| KPI | KPI_NL_UC4_04 |
| Test objective | Measure the data rate used between the UE and the edge server. |
| Pre-conditions | 5G RAN is working and the UE is already connected to it. |
| Targeted result | AR content streaming with the following data transmission.<br>Data transmission:<br>- uplink throughput <=20Mbps<br>- downlink throughput <= 50mbps |
| Test procedure | 1. Check that the UE is properly connected to the 5G network (IP connectivity established). |
| Collecting data | Collect logs in the mobile user device and the edge server. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 52, TC_KPI_UC4_03, Service Availability**

| Test Case ID | TC_KPI_UC4_03 |
|---|---|

| | |
|---|---|
| Summary | Service Availability |
| UC number or AOEP | UC4 |
| KPI | KPI_SL_UC4_01 |
| Test objective | The percentage of time (%) the AR streaming service is delivered to the mobile users. |
| Pre-conditions | 5G network is operational, and the UE is connected to both RAN and edge. Mobile Users are connected to the relevant nApp AR client application. |
| Targeted result | Service availability >= 99.999%. |
| Test procedure | 2. Check that the UE is properly connected to the 5G edge through the RAN (IP connectivity established).<br>3. Check that the AR content streaming can reach the UE.<br>4. Perform availability checks for all interconnected components of the UC. |
| Collecting data | The nApp is up and running and a log is created to provide service availability information. |
| Test verdict | The service availability will be monitored between the client at the UE and the server at the edge. |

### 3.3.5. UC5 TC tables

UC5 will develop a novel feature for the detection of hazardous driving events and risk assessment of road networks, combining aggregated data from an ML model trained on the edge with real-time driving behaviour data. In particular, the ML model will provide an overview of the average risk level of a road, based on the frequency of harsh events (harsh braking, harsh acceleration, speeding, mobile use). The UC will then employ 5G network capabilities for the detection of harsh events in real-time, thus warning users if there is an increase in risk level of the road segment due to more frequent occurrence of hazardous events.

In total 5 functional tests and 5 KPI evaluation tests have been defined for UC5 in the sub-chapters below.

#### *3.3.5.1. UC5 functional TC tables*

As done with other 5G-IANA Use Cases, the UC5 functional tests aim to secure end-to-end connectivity and proper function of the designed feature. The first test aims to ensure connectivity of the OBU to the 5G network, while the second test aims to ensure connectivity of the smartphone to the OBU via WiFi, and the third test is to secure the connectivity of the system (smartphone + OBU) to the central cloud. Once connectivity tests are done, the next is to ensure that the system functions correctly, namely that notifications are received (fourth test) and transmitted (fifth test).

**Table 53, TC_FT_UC5_01, OBU - 5G Network Connectivity Test**

| Test Case ID | TC_FT_UC5_01 |
|---|---|
| Summary | OBU can attach and register to the 5G network |
| UC number or AOEP | UC5 |
| KPI | n/a |
| Test objective | The OBU is a key HW components required for UC3 as it provides connectivity to the network. This test checks if it is successfully connected to the 5G network of 5G-IANA testbed(s). |
| Pre-conditions | OBU is powered on and operational, SIM card is inserted – to be confirmed by accessing dedicated LiNKS management console which is not connected over 5G-IANA testbed 5G network. |
| Targeted result | The OBU are connected to the 5G-IANA testbed 5G network and can exchange data with the edge server. |
| Test procedure | 1. Connect to the OBU via LiNKS management console.<br>2. Check that the OBU has successfully connected to 5G network (5G modem is attached and registered to the 5G network and has obtained IP address).<br>3. Generate ICMP request from OBU to qMON Ref Server deployed in the edge server.<br>4. Check if ICMP response has been successfully received. |
| Collecting data | Check for ICMP response in management console. |
| Test verdict | ICMP responses successfully received: PASS<br>ICMP response not received: FAIL |

**Table 54, TC_FT_UC5_02, OBU - Smartphone Connectivity Test**

| Test Case ID | TC_FT_UC5_02 |
|---|---|
| Summary | Check Smartphone to OBU Connectivity |
| UC number or AOEP | UC5 |
| KPI | n/a |
| Test objective | Confirm the connectivity between the smartphone and the OBU via WiFi. |
| Pre-conditions | n/a |
| Targeted result | Smartphone connected to the OBU |
| Test procedure | 1. Connect the smartphone to the OBU via LiNKS management console. |
| Collecting data | Manual check. |
| Test verdict | Smartphone connected to the OBU: PASS<br>Smartphone not connected to the OBU: FAIL |

**Table 55, TC_FT_UC5_03, System - Cloud Connectivity Test**

| Test Case ID | TC_KPI_UC5_03 |
|---|---|
| Summary | Check system (Smartphone + OBU) to Central Cloud Connectivity |
| UC number or AOEP | UC5 |
| KPI | n/a |
| Test objective | Confirm the connectivity between the system and the Central cloud (via the edge server). |
| Pre-conditions | All previous tests (TC_KPI_UC5_01-02). |
| Targeted result | nApp component (logging) is receiving a log from another nApp Component (network monitoring). |
| Test procedure | 1. Send a log of the "Active Network Monitoring Module" nApp component located in the smartphone to the "UC-Specific Log Reporting Service" nApp component located in the central cloud.<br>2. Check that the log was successfully received and stored. |
| Collecting data | Manual check. |
| Test verdict | Log was successfully received and stored: PASS<br>Log was successfully received and stored: FAIL |

**Table 56, TC_FT_UC5_04, End User notification receipt**

| Test Case ID | TC_FT_UC5_04 |
|---|---|
| Summary | End user's UI receives hazardous event notifications |
| UC number or AOEP | UC5 |
| KPI | n/a |
| Test objective | To check driver can receive notifications generated by the nApp(s). |
| Pre-conditions | All previous tests (TC_KPI_UC5_01-03). |
| Targeted result | User is able to receive hazardous event notifications provided by the service. |
| Test procedure | 1. Users connects to the system via their smartphone and receives notifications generated by the nApp(s). |
| Collecting data | Manual check. |
| Test verdict | Hazardous event notifications are available as expected: PASS<br>Hazardous event notifications are not available (or not updated regularly, etc.): FAIL |

**Table 57, TC_FT_UC5_05, System notification transmission**

| Test Case ID | TC_FT_UC5_05 |
|---|---|
| Summary | System transmits hazardous event detection |

| | |
|---|---|
| UC number or AOEP | UC5 |
| KPI | n/a |
| Test objective | To check whether the system can properly transmit detection generated by the nApp(s). |
| Pre-conditions | All previous tests (TC_KPI_UC5_01-04). |
| Targeted result | The nApp properly transmits hazardous event notifications. |
| Test procedure | 1. Users connects to the system via their smartphone and performs hazardous driving events (harsh braking / acceleration, speeding, mobile use) that should be transmitted by the nApp(s). |
| Collecting data | Manual check. |
| Test verdict | Hazardous event detection is transmitted as expected: PASS<br>Hazardous event detection is not transmitted: FAIL |

#### *3.3.5.2. UC5 KPI TC tables*

KPI tests for UC5 aim at extracting information on the performance of the network and the system and the service it provides. Thus, UC5 will monitor Round Trip Time, reliability and availability, E2E latency (as this is critical for the UC) and deployment time. The following tables describe the KPI tests for UC5.

**Table 58, TC_KPI_UC5_01, RTT**

| Test Case ID | TC_KPI_UC5_01 |
|---|---|
| Summary | 5G Round Trip Time (RTT): RTT between OBU and local edge server |
| UC number or AOEP | UC5 |
| KPI | KPI_NL_UC5_01 |
| Test objective | To measure/test and evaluate RTT between the OBU and the local edge server. Low latency is required in the context of UC5 to achieve high fidelity in the transferring of live data between drivers. The RTT represents a baseline for the minimum transport latency, which is one component of the E2E latency. |
| Pre-conditions | 5G network is operational, and the smartphone is connected via the 5G network to the local edge server. The OBU will handle the connection. |
| Targeted result | Average RTT <= 20 ms |
| Test procedure | 1. Check that OBU is properly connected to the 5G network (IP connectivity established).<br>2. Ping from the Far Edge to the edge server. |
| Collecting data | Collect logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 59, TC_KPI_UC5_02, Reliability**

| Test Case ID | TC_KPI_UC5_02 |
|---|---|
| Summary | Reliability |
| UC number or AOEP | UC5 |
| KPI | KPI_SL_UC5_02 |
| Test objective | Measure and calculate the probability of successfully delivered packets from the Far Edge to the edge server within a target latency threshold i.e., the packets are not either erroneous, lost, or arrive too late. UC5 requires near-real time response rates to process hazardous events and transmit the information to nearby vehicles, and to achieve a non-tedious experience. |
| Pre-conditions | 5G network is operational, and the smartphone is connected via the 5G network to the local edge server. The OBU will handle the connection. The smartphone and OBU are connected via WiFi. |
| Targeted result | Reliability >= 99.99% (packet error rate < $10^{-4}$) |
| Test procedure | 1. Check that the system is properly connected to the 5G network (IP connectivity established).<br>2. Run monitoring tool. |
| Collecting data | Logs of monitoring tool (e.g., qMON or iPERF). |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 60, TC_KPI_UC5_03, E2E Latency**

| Test Case ID | TC_KPI_UC5_03 |
|---|---|
| Summary | E2E Latency |
| UC number or AOEP | UC5 |
| KPI | KPI_SL_UC5_01 |
| Test objective | Evaluate the duration required to send data between two points of the service chain. |
| Pre-conditions | 1. 5G network is operational, and the OBU is connected via the 5G network to the local edge server.<br>2. Edge Server is connected to the Central Cloud.<br>3. End Users are connected to the relevant nApp component (smartphone application). |
| Targeted result | Average time for request/response transactions < 500ms |
| Test procedure | 1. Perform measurements in the Far Edge i.e., in OBUs. |
| Collecting data | Measurements will be logged in the Central Cloud. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 61, TC_KPI_UC5_04, Service availability**

| Test Case ID | TC_KPI_UC5_04 |
|---|---|
| Summary | Service Availability |
| UC number or AOEP | UC5 |
| KPI | KPI_SL_UC5_03 |
| Test objective | The percentage of time the service is offered properly. |
| Pre-conditions | 1. 5G network is operational, and the OBU is connected via the 5G network to the local edge server.<br>2. Edge Server is connected to the Central Cloud.<br>3. End Users are connected to the relevant nApp component (smartphone application). |
| Targeted result | Service availability >= 99.999% |
| Test procedure | 1. Check that the OBU is properly connected to the 5G network (IP connectivity established).<br>2. Check that the smartphone is properly connected to the OBU (WiFi connectivity established).<br>3. Check that the hazardous event notifications can reach the End-Users.<br>4. Perform availability checks for all interconnected components of the UC. |
| Collecting data | Measurements will be logged in the Central Cloud. |
| Test verdict | Compare results gained through the test to targeted results value. E2E availability will be monitored between each interconnected component. |

**Table 62, TC_KPI_UC5_05, Service deployment time**

| Test Case ID | TC_KPI_UC5_05 |
|---|---|
| Summary | Service deployment time |
| UC number or AOEP | UC5 |
| KPI | KPI_SL_UC5_04 |
| Test objective | To measure/test and evaluate service deployment time, the duration required for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.). |
| Pre-conditions | AOEP platform is operational, testbed is fully operational, requested smartphone/OBUs are connected to the 5G network. Test scripts (deployment and scale-out) are prepared. |
| Targeted result | Initial service deployment time <= 3 min<br>Service scale-out time <= 1 min<br>Service design time <= 60 min |
| Test procedure | 1. Check all pre-conditions are met.<br>2. Start service deployment script. |

| | |
|---|---|
| | 3. Start service scale-out script. |
| Collecting data | AOEP logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

### 3.3.6. UC6 TC tables

UC6 will be initiated at the DML Orchestrator that will chain multiple ML nodes as VNFs on the available OBUs and returns network predictions based on the past network behaviour, which can be utilized in V2X communication. The goal is to minimize the data collection overhead through utilizing a distributed Machine Learning approach, i.e., instead of collecting large amounts of network monitoring data to be centrally analysed, the ML analysis/prediction model is distributed on the AFs/NFs located at the Far Edge. The deployed VNFs will collect the network state information such as Round-Trip Time (RTT) and Data Rates, which are used to train the model in a federated fashion.

In total 5 functional tests and 2 KPI evaluation tests have been defined for UC6 in the sub-chapters below.

#### *3.3.6.1. UC6 functional TC tables*

Similar to the rest of the 5G-IANA UCs, UC6 functional tests were mostly designed to ensure end-to-end connectivity for the functionalities required to fully demonstrate this use case. Tests start examining the connectivity of components found in the Edge, continue with connectivity tests to the Central Cloud and finally the E2E chain is examined. Additionally, a test is performed to ensure that the network behaviour is being continuously collected and pre-processed to create training data.

**Table 63, TC_FT_UC6_01, DMLO receives worker node details**

| Test Case ID | TC_FT_UC6_01 |
|---|---|
| Summary | Details of the worker node at the DMLO (Distributed Machine Learning Orchestrator) |
| UC number or AOEP | UC6 |
| KPI | n/a |
| Test objective | To check if the DMLO receives the details of all the available worker nodes for Client Selection. This should be a continuous process that repeats after every interval. |
| Pre-conditions | The DMLO should be connected to all the active worker nodes. |

| | |
|---|---|
| Targeted result | DMLO should get complete information regarding the worker nodes needed for client selection. |
| Test procedure | 1. Get a new worker node to join the DML training regime.<br>2. Check if the worker node sends its details (such as location, availability of GPU, or mobility details) to FERI (Far edge Resource Inventory).<br>3. Check if DMLO requests FERI for node details before the start of the DML task.<br>4. Check if FERI updates the DMLO with information regarding all the worker nodes.<br>5. Check if DMLO receives the ML stats from each worker node.<br>6. Check if all the tasks mentioned above are repeated after a specific interval to keep DMLO updated on any changes in worker nodes. |
| Collecting data | Check DMLO Logs. |
| Test verdict | DMLO receives the information regarding the worker nodes both from FERI and worker nodes: PASS<br>Any of the mentioned test procedures report error or failure: FAIL |

**Table 64, TC_FT_UC6_02, Client selection**

| Test Case ID | TC_FT_UC6_02 |
|---|---|
| Summary | Client Selection |
| UC number or AOEP | UC6 |
| KPI | n/a |
| Test objective | To check if the DMLO selects worker nodes for performing DML training tasks based on the ML configuration file provided by AEOP. |
| Pre-conditions | DMLO should have the complete list/details of the worker nodes. |
| Targeted result | DMLO selects the worker nodes from a pool of worker nodes to perform an ML training task. |
| Test procedure | 1. Check if DMLO receives an ML configuration file from AOEP that contains information like clients per round, ML model settings, termination criteria, etc., from the user.<br>2. Check if DMLO has an updated list of currently available worker nodes and their status.<br>3. Check if DMLO selects clients/worker nodes for each training cycle. |
| Collecting data | Check DMLO logs for the selected clients for each training cycle. |
| Test verdict | Client selection for each training cycle: PASS<br>Any of the mentioned test procedures report error or failure: FAIL. |

**Table 65, TC_FT_UC6_03, Collection and Pre-processing of training data**

| Test Case ID | TC_FT_UC6_03 |
|---|---|

| | |
|---|---|
| Summary | Collection and Pre-processing of training data |
| UC number or AOEP | UC6 |
| KPI | n/a |
| Test objective | To confirm the proper working of Network Monitoring VNF and Data Pre-processing VNF. |
| Pre-conditions | The GNSS and 5G modules have to be connected to the worker node. |
| Targeted result | Training data collection by the Network Monitoring VNF and pre-processing the collected data by Data Pre-Processing VNF. |
| Test procedure | 1. Check if the GNSS and 5G modules are physically connected to the OBUs.<br>2. Check if the Network Monitoring VNF can collect and store training data.<br>3. Check if the data collected is sent to Data Pre-processing VNF.<br>4. Check if the Data Pre-Processing VNF can prepare the data for the training process. |
| Collecting data | Check the logs. |
| Test verdict | Network Monitoring VNF and Data Pre-Processing VNF execute their task flawlessly: PASS.<br>Errors/Failures in tasks carried out by Network Monitoring VNF and Data Pre-Processing: FAIL. |

**Table 66, TC_FT_UC6_04, Local Training**

| Test Case ID | TC_FT_UC6_04 |
|---|---|
| Summary | Local Training |
| UC number or AOEP | UC6 |
| KPI | n/a |
| Test objective | To confirm that the local training is performed on each selected worker node during the training cycle of the DML task. |
| Pre-conditions | Locally collected data, training configurations, and models for the training node should be available at each worker node before the start of local training. |
| Targeted result | Local training should be conducted using locally collected data at each worker node. |
| Test procedure | 1. Check if the training data from the pre-processing node is available at Local Training VNF.<br>2. Check if the training model from DMLO is available at the worker node.<br>3. Check if the local training process is carried out. |
| Collecting data | Logs at the worker node. |
| Test verdict | Local Training completed: PASS<br>Any of the mentioned test procedures report error or failure: FAIL |

**Table 67, TC_FT_UC6_05, Aggregation of Models**

| Test Case ID | TC_FT_UC6_05 |
|---|---|
| Summary | Aggregation of Models |
| UC number or AOEP | UC6 |
| KPI | n/a |
| Test objective | Generation of the global model by aggregating all the local models after every training cycle. |
| Pre-conditions | Locally trained models from all the selected worker nodes should be available at the Aggregator VNF. |
| Targeted result | After every training cycle, a global model should be created at the Aggregator VNF. |
| Test procedure | 1. Check if local training is being carried out on all the selected worker nodes and sent to Aggregator VNF.<br>2. Check if Aggregator VNF receives the locally trained model from worker nodes.<br>3. Check if Aggregator VNF receives the ML configuration file from which it extracts "Type of Aggregation."<br>4. Check if the Global model is formed from all the received locally trained models at Aggregator VNF. |
| Collecting data | Logs at Aggregator VNF. |
| Test verdict | Global model created after every training cycle: PASS<br>Any of the mentioned test procedures report error or failure: FAIL |

### 3.3.6.2. *UC6 KPI TC tables*

To measure and evaluate the KPIs in UC6, a custom built KPI monitoring tool is deployed both at the Edge and Far Edge (OBUs). The task of this tool is to collect all the stats/metrics needed to evaluate the KPIs (global model download time, model upload time, aggregation time, inference time, or model training time). The monitoring tool is deployed at both locations (Edge and Far Edge) because some of the stats, like aggregation time, are available at the Edge, and some stats, like inference time and model training time, are only available at the Far Edge.

**Table 68, TC_KPI_UC6_01, 5G RTT**

| Test Case ID | TC_KPI_UC6_01 |
|---|---|
| Summary | 5G Round Trip Time (RTT): Round-Trip Latency in the 5G network |
| UC number or AOEP | UC6 |

| | |
|---|---|
| KPI | KPI_NL_UC6_01 |
| Test objective | To measure/test and evaluate RTT between the UE and the local edge server (suitable RTT allows for smooth video streaming). "UE" also refers to RSU, OBU, and other devices directly connected to 5G network.<br>The RTT represents a baseline for the minimum transport latency, which is one component of the E2E latency. |
| Pre-conditions | 5G network is operational, and UE is connected via the 5G network to the local edge server. The monitoring tool agent is operational in UE and the monitoring tool reference server are operational at the edge server. A RTT "work order" is defined for the monitoring tool. |
| Targeted result | Average RTT <= 20 ms |
| Test procedure | 1. Check that UE is properly connected to the 5G network (IP connectivity established).<br>2. Run "work order". |
| Collecting data | Monitoring tool logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 69, TC_KPI_UC6_02, Service Level KPIs Evaluation**

| Test Case ID | TC_KPI_UC6_02 |
|---|---|
| Summary | Service Level KPIs Evaluation |
| UC number or AOEP | UC6 |
| KPI | KPI_SL_UC6_01 to KPI_SL_UC6_11 |
| Test objective | To evaluate the following KPIs:<br>• Global Model Download Time<br>• Model upload time<br>• Aggregation Time<br>• Data Pre-Processing Time<br>• Model Training Time<br>• Inference Time<br>• Latency Prediction Error<br>• Network traffic overhead (UL)<br>• Network traffic overhead (DL)<br>• Local training success rate<br>• Global training success rate |
| Pre-conditions | 5G network and all the VNFs related to DML are operational. The monitoring tool agent is deployed on both Edge and Far Edge. |
| Targeted result | UC6 targets<br>• Global Model Download Time < 2 sec<br>• Model upload time < 2 sec<br>• Aggregation Time < 5 sec<br>• Data Pre-Processing Time < 1 min<br>• Model Training Time < 4 min |

| | |
|---|---|
| | • Inference Time < 200 msec<br>• Latency Prediction Error < 10%<br>• Network traffic overhead (UL) < 10MB<br>• Network traffic overhead (DL) < 10MB<br>• Local training success rate > 90%<br>• Global training success rate > 90% |
| Test procedure | 1. Check if the DML task is initiated properly.<br>2. Start monitoring tool agent.<br>3. Wait for the completion of the DML task<br>4. Extract the KPIs from monitoring tool and evaluate them. |
| Collecting data | Monitoring tool logs on Edge and Far Edge. |
| Test verdict | Compare results gained through the test to targeted results value. |

### 3.3.7. UC7 TC tables

UC7 belongs to the hazard notification use case category. It will demonstrate situational awareness for first responders in the case of an accident in a cross-border road tunnel. The UC is based on collecting data from multiple sources, including cameras, environmental sensors, RSUs and OBUs, and representing them to the first responders. In this particular case, utilizing the 5G network simplifies cross-border collaboration among first responders from both bordering states without a need of using dedicated UEs as is usual practice today (e.g., each of the two bordering countries having its own communication system).

The majority of UC7 test will be performed by the Internet Institute's own product qMON, which is a 5G-assured monitoring and testing solution for unified mobile, cloud and fixed systems operations. It enables end-to-end automated measurements in live environments and can also provide emulations of active end-to-end users and various services. Since qMON is designed on the principle of distributed autonomous agents, it provides zero data loss while supported by centralized cloud-based management. While it already provides hundreds of Key Performance indicators for multiple purposes, customization for specific needs can be also added (e.g., to support specific requirements in 5G-IANA).

In total 8 functional tests and 6 KPI evaluation tests are defined for the UC7 in the sub-chapters below.

#### *3.3.7.1. UC7 functional TC tables*

Similar to the rest of the 5G-IANA UCs, UC7 functional tests were mostly designed to ensure end-to-end connectivity and operability of nApp components to make sure the UC can be fully demonstrated. Tests start with examining connectivity between the cross-border test sites and continue with connectivity test of certain HW components (edge, RSU, OBU, UE). Finally, operability of certain components is examined.

**Table 70, TC_FT_UC7_01, VPN tunnel Connectivity Test**

| Test Case ID | TC_FT_UC7_01 |
|---|---|
| Summary | VPN tunnel TS Ljubljana - Nokia Ulm is operational. |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | Active VPN tunnel between TS Ljubljana testbed and Nokia Ulm testbed is required in order to enable cross-border scenario proposed by UC7. This test checks only whether the VPN tunnel is established. For testing tunnel performances see KPI_NL_UC7_05 test (TC_KPI_UC7_05). |
| Pre-conditions | qMON system components deployed in TS and Nokia MECs are up & running (verified in administrative dashboard). |
| Targeted result | Received response to ICMP request sent from either TS and/or Nokia side. |
| Test procedure | 1. In AOEP dashboards check the qMON components deployed in TS and Nokia testbed (qMON Agent and qMON Reference Server) are active.<br>2. Trigger ICMP request from qMON agent in TS testbed to qMON Ref. Server in Nokia testbed.<br>3. Vice-versa to previous action point (trigger ICMP request from qMON agent in Nokia testbed to qMON Ref. Server in TS testbed).<br>4. Check responses of action points 2 and 3. |
| Collecting data | Check qMON logs |
| Test verdict | ICMP responses successfully received in both directions: PASS<br>ICMP response not received (timeout) at least in one direction: FAIL |

**Table 71, TC_FT_UC7_02, RSU/OBU – EDGE/DN Connectivity Test**

| Test Case ID | TC_FT_UC7_02 |
|---|---|
| Summary | RSU and OBU can establish the PDU Connection to EDGE/DN |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | RSU and OBU are key HW components required for UC 7 in order to acquire field data. This test checks if they are successfully connected to the 5G network of 5G-IANA testbed(s). |
| Pre-conditions | RSU and OBU are powered on and operational, SIM card is inserted – to be confirmed by accessing dedicated LiNKS management console which is not connected over 5G-IANA testbed 5G network. |

| | |
|---|---|
| Targeted result | RSU and OBU are connected via the 5G-IANA testbed 5G network to the EDGE, and RSU and OBU can exchange data with Edge. |
| Test procedure | 1. Connect to RSU (and OBU) via LiNKS management console.<br>2. Check RSU (and OBU) has successfully connected to 5G network (5G modem is attached and registered to the 5G network, has established a PDU connection to the EDGE, and has obtained IP descriptors).<br>3. Generate ICMP request from RSU (and OBU) to qMON Ref Server deployed in Edge.<br>4. Check if ICMP response has been successfully received. |
| Collecting data | Check for ICMP response in management console. |
| Test verdict | ICMP responses successfully received: PASS<br>ICMP response not received: FAIL |

**Table 72, TC_FT_UC7_03, Sensors operational**

| Test Case ID | TC_FT_UC7_03 |
|---|---|
| Summary | Sensors are operational (output value is updated whenever measured quantity changes its state/value) |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | To confirm a sensor is operational, i.e., the sensor is sending data and reacts on changes of the quantity it measures by updating its value. |
| Pre-conditions | Sensor is physically connected to the RSU. SW component that enables collecting data from physical sensor is installed at RSU. |
| Targeted result | The measured quantity change is followed by value update at the corresponding SW component. |
| Test procedure | 1. Check the sensor is physically connected to RSU.<br>2. Connect to RSU via LiNKS management console.<br>3. Check the output value of the SW component serving the particular sensor.<br>4. Trigger measured quantity change, e.g., put the temperature sensor into the refrigerator.<br>5. Check the output value of the SW component serving the particular sensor has changed accordingly. |
| Collecting data | Check logs. |
| Test verdict | Measured value can be accessed and the value changes according to the environment condition changes: PASS.<br>Measure value cannot be accessed, or the value does not change according to the environment condition changes: FAIL. |

**Table 73, TC_FT_UC7_04, Camera operational**

| Test Case ID | TC_FT_UC7_04 |
|---|---|
| Summary | Camera is operational |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | To confirm the camera is operational, i.e., it streams video. |
| Pre-conditions | Camera is physically connected to the RSU. nApp component (Streaming) that enables collecting data from physical sensor is installed at RSU. |
| Targeted result | nApp component (Streaming) is receiving video stream from the camera. |
| Test procedure | 1. Check the camera is physically connected to RSU.<br>2. Connect to RSU via LiNKS management console.<br>3. Check the nApp component (streaming) is receiving video stream from the camera. |
| Collecting data | Manual/visual check. |
| Test verdict | Video stream received: PASS.<br>Video stream not received: FAIL. |

**Table 74, TC_FT_UC7_05, Components operational**

| Test Case ID | TC_FT_UC7_05 |
|---|---|
| Summary | Distributed components (installed at RSU and OBU) are able to communicate with edge/cloud components |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | Operation ability of nApp components requires that there are no constraints in place for nApp components to exchange data among themselves. |
| Pre-conditions | UC7 nApp components or their corresponding parts (Monitoring, Analytics, Streaming) are deployed at the RSU, OBU and at the Edge and are up & running (verified in administrative dashboard). The PDU connection between the RSU/OBU and the edge server is established (as verified in functional test TC_FT_UC7_02).<br>Note: Not all components are deployed at every node (OBU, RSU, Edge). |
| Targeted result | Data, collected by sensors, are written in Monitoring database (placed at Edge) and are accessible by the Analytics component (placed at Edge). Video-stream from the camera connected to RSU is forwarded to the Streaming component placed at Edge. |
| Test procedure | 1. Connect to Monitoring database and check for data sent by sensors connected to RSU. |

| | |
|---|---|
| | 2. Connect to Analytics component and check it receives data from the Monitoring database.<br>3. Connect to Streaming component and check it receives video-stream from the camera. |
| Collecting data | Logs of each single nApp component (Monitoring, Analytics, Streaming). Manual check. |
| Test verdict | Data and video-stream are received as expected: PASS<br>Data or video-stream is not received: FAIL |

**Table 75, TC_FT_UC7_06, CAM simulator operational**

| **Test Case ID** | TC_FT_UC7_06 |
|---|---|
| Summary | Simulator of ETSI Cooperative Awareness is sending data to the Monitoring database |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | Verifies whether Simulator of ETSI Cooperative Awareness VNF is operational and is sending data to the Monitoring database. |
| Pre-conditions | Simulator of ETSI Cooperative Awareness VNF and Monitoring VNF are deployed in testbed and are up & running (verified in administrative dashboard). |
| Targeted result | Data generated by Simulator of ETSI Cooperative Awareness are recorded in the Monitoring database. |
| Test procedure | 1. Connect to the Monitoring database and check for data sent by the Simulator of ETSI Cooperative Awareness. |
| Collecting data | Monitoring database and Monitoring VNF logs. |
| Test verdict | Data are received as expected: PASS<br>Data are not received: FAIL |



**Table 76, TC_FT_UC7_07, UE – EDGE Connectivity Test**

| **Test Case ID** | TC_FT_UC7_07 |
|---|---|
| Summary | UE can be connected to the Edge, and connect to interfaces (https, rstp) exposed by the service |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | To check that the UE can access services provided by the nApp(s). |
| Pre-conditions | UE is powered on, SIM card is inserted. |

| | |
|---|---|
| Targeted result | UE is able to access interfaces exposed by the service. |
| Test procedure | 1. Connect UE to the 5G-IANA testbed 5G network.<br>2. Check UE is connected (UE registered, IP descriptors obtained).<br>3. Check access to Analytics VNF (via https), e.g., use curl command.<br>4. Check access to Streaming VNF (via rtps), e.g., use rtsp-curl command. |
| Collecting data | Check for response (curl, rtsp-curl) in command-prompt. |
| Test verdict | Responses from https and rtsp interfaces successfully received: PASS<br>At least one response not received: FAIL |

**Table 77, TC_FT_UC7_08, UE receives sensor data**

| Test Case ID | TC_FT_UC7_08 |
|---|---|
| Summary | End user's UE receives sensors data and video stream<br>a. from sensors deployed in home network<br>b. from sensors deployed in cross-border network |
| UC number or AOEP | UC7 |
| KPI | n/a |
| Test objective | To check user can access content provided by the nApp(s). |
| Pre-conditions | TC_FT_UC7_07 passed. |
| Targeted result | User is able to access the content provided by the service. |
| Test procedure | 1. From the UE connect to the Analytics VNF.<br>2. Access data provided by sensors deployed in home network: check in Grafana dashboards whether data are displayed and updated regularly.<br>3. Access data provided by sensors deployed in cross-border network: check in Grafana dashboards whether data are displayed and updated regularly.<br>4. From the UE connect to the Streaming VNF.<br>5. Access video-stream from the camera deployed in home network.<br>6. 6. Access video-stream from the camera deployed in cross-border network. |
| Collecting data | Manual check for data and video-stream. |
| Test verdict | Data and video-stream are available as expected: PASS<br>Data or video-stream not available (or not updated regularly, video is frozen, etc.): FAIL |

### *3.3.7.2. UC7 KPI TC tables*

The KPIs chosen for evaluation in UC7 primarily target performances of the 5G network which is expected to enable the nApp to stream video without interruptions. Then, KPIs targets cross test sites VPN performance, and finally service deployment and scale-out time is evaluated to demonstrate specific capabilities of the AOEP platform.

**Table 78, TC_KPI_UC7_01, 5G RTT**

| Test Case ID | TC_KPI_UC7_01 |
|---|---|
| Summary | 5G Round Trip Time (RTT): RTT between UE and local edge server |
| UC number or AOEP | UC7 |
| KPI | KPI_NL_UC7_01 |
| Test objective | To measure/test and evaluate RTT between the UE and the local edge server (suitable RTT allows for smooth video streaming). "UE" also refers to RSU, OBU and other devices directly connected to 5G network.<br>The RTT represents a baseline for the minimum transport latency, which is one component of the E2E latency. |
| Pre-conditions | 5G network is operational, UE is connected via the 5G network to the local edge server, the qMON Agent is operational in UE and the qMON Reference Server is operational at the edge server. qMON RTT "work order" is defined. |
| Targeted result | Average RTT <= 20 ms |
| Test procedure | 1. Check UE is properly connected to the 5G network (IP connectivity established).<br>2. Run "work order". |
| Collecting data | qMON logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 79, TC_KPI_UC7_02, Reliability**

| Test Case ID | TC_KPI_UC7_02 |
|---|---|
| Summary | Reliability: Minimum reliability required to assure the proper service operation |
| UC number or AOEP | UC7 |
| KPI | KPI_NL_UC7_02 |
| Test objective | To measure/test and evaluate reliability by determining the packet loss rate (PLR) between the UE and the local edge server. The packet loss rate is defined as the fraction of the total transmitted packets that did not arrive at the receiver. |

| | |
|---|---|
| | "UE" also refers to RSU, OBU and other devices directly connected to 5G network. |
| Pre-conditions | 5G network is operational, UE is connected to the local edge server via the 5G network, qMON Agent is operational in UE and qMON Reference Server is operational at the edge server. qMON Reliability "work order" is defined. |
| Targeted result | Reliability >= 99.99% (i.e., Packet Loss Rate< $10^{-4}$) |
| Test procedure | 1. Check UE is properly connected to the 5G network (IP connectivity established).<br>2. Run "work order". |
| Collecting data | qMON logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 80, TC_KPI_UC7_03, User data rates**

| Test Case ID | TC_KPI_UC7_03 |
|---|---|
| Summary | Uplink and Downlink user throughput rates |
| UC number or AOEP | UC7 |
| KPI | KPI_NL_UC7_03 |
| Test objective | To measure/test and evaluate UL and DL user throughput rates between the UE and the local edge server. The throughput refers to ratio of data transmitted in unit of time.<br>"UE" also refers to RSU, OBU and other devices directly connected to 5G network. The terms "throughput rate" and "user data rate" are used synonymously in 5G-IANA. |
| Pre-conditions | 5G network is operational, UE is connected to the local edge server via the 5G network, qMON Agent is operational in UE and qMON Reference Server is operational at the edge server. qMON data rate "work order" is defined. |
| Targeted result | UL user data rate >= 20Mb/s and<br>DL user data rate >= 50Mb/s |
| Test procedure | 1. Check UE is properly connected to the 5G network (IP connectivity established).<br>2. Run "work order". |
| Collecting data | qMON logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 81, TC_KPI_UC7_04, Jitter**

| Test Case ID | TC_KPI_UC7_04 |
|---|---|
| Summary | Jitter: the maximum accepted average jitter between the UE and edge server |
| UC number or AOEP | UC7 |
| KPI | KPI_NL_UC7_04 |
| Test objective | To measure/test and evaluate jitter between the UE and the local edge server. The Jitter is the variation in time delay between when a signal is transmitted and when it's received over a network connection, measuring the variability in ping.<br>"UE" also refers to RSU, OBU and other devices directly connected to 5G network. |
| Pre-conditions | 5G network is operational, UE is connected to the local edge server via the 5G network, the qMON Agent is operational in UE and the qMON Reference Server is operational at the edge server. qMON data rate "work order" is defined. |
| Targeted result | Average jitter of 2 ms |
| Test procedure | 1. Check UE is properly connected to the 5G network (IP connectivity established).<br>2. Run "work order". |
| Collecting data | qMON logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 82, TC_KPI_UC7_05, VPN performance**

| Test Case ID | TC_KPI_UC7_05 |
|---|---|
| Summary | Cross-border VPN connectivity performance |
| UC number or AOEP | UC7 |
| KPI | KPI_NL_UC7_05 |
| Test objective | To measure/test and evaluate max. accepted RTT, packet loss rate, and the user throughput rates between the local edge servers of the two testbeds. |
| Pre-conditions | Edge servers in both testbeds are operational, VPN is established between the local edge servers of the testbeds, qMON Reference Servers and qMON Agents are operational at both ends. qMON "VPN work order" is defined.<br>Note: The VPN connection between the local edge servers is routed via the public Internet. Therefore, higher RTT are expected in comparison to a cross-border deployment, where a connection with a subscribed SLA can be realized. |

| | |
|---|---|
| Targeted result | RTT <= 150 ms<br>Packet loss rate < $10^{-4}$<br>User data rate: > 20 Mbit/s (UL), > 50 Mbit/s (DL) |
| Test procedure | 1. Check the VPN is up and running (IP connectivity established).<br>2. Run “work order”. |
| Collecting data | qMON logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

**Table 83, TC_KPI_UC7_06, Service deployment and scale-out time**

| Test Case ID | TC_KPI_UC7_06 |
|---|---|
| Summary | Service deployment and scale-out time |
| UC number or AOEP | UC7 |
| KPI | KPI_SL_UC7_01 |
| Test objective | To measure/test and evaluate service deployment time, the duration needed for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.). |
| Pre-conditions | The AOEP platform is operational, the testbeds are fully operational, the requested UEs/RSUs/OBUs are connected to the local edge servers via the 5G networks. Test scripts (deployment and scale-out) are prepared. |
| Targeted result | Initial service deployment time <= 3 min<br>Service scale-out <= 1 min |
| Test procedure | 1. Check all pre-conditions are met.<br>2. Start service deployment script.<br>3. Start service scale-out script. |
| Collecting data | AOEP logs. |
| Test verdict | Compare results gained through the test to targeted results value. |

## 3.4. Overview of the tools that will be utilized for KPI measurements

In [6], the various tools used for KPI measurement are distinguished in five types based on how they are deployed:

- Tools that use a Client-Server approach to measure E2E KPIs, e.g., throughput or Round-Trip time (RTT) latency. These tools usually perform measurements in a stateful fashion e.g., via TCP sessions.

- Tools that are called single node. These tools send traffic to node or the service it hosts and measure the response times. They can be utilized to measure service availability.
- Tools that operate In-network. These tools observe the traffic flows and log the related statistics. They can be also utilized to measure KPIs such as RTT latency or packet loss rate.
- Tools called “In-hypervisor”. These are deployed on the host OS of the servers and can provide highly detailed information concerning the services deployed in said servers.
- Hardware based tools, such as UE emulators, typically used to test the lower layer of a 5G network.

Table 84 collects the tools that will be utilized in 5G IANA for KPI measurements with references to UCs that utilized them and the KPI that is measured, so they can be easily reviewed by third party experimenters.

**Table 84 Categorization of the tools that will be utilized for KPI measurements in 5G IANA**

| Tool Category | Tool names (UC - KPI) |
|---|---|
| Client-Server | Iperf (UC3 - User Data Rate, UC3 – E2E latency), Active Network Monitoring Tool (UC3 – Mobility Interruption Time) |
| Single Node | ntopng (UC2 – E2E latency), qMON (UC7 – RTT, UC7 Reliability, Throughput, Jitter), Ping (UC 1 to 5 – RTT latency, UC1/2 - E2E reliability) |
| In-network | Wireshark (UC2 – E2E latency, UC3 – E2E reliability), G-NetTrack Lite (UC5 – Reliability) |
| In-hypervisor | Unity VR server (UC3 – Application Jitter) |
| Hardware | - |

# 4. TEST AUTOMATION ASPECTS

## 4.1. Introduction

5G-IANA WP5 is tasked to provide open interfaces to monitor and operate UCs enabling automated testing. Therefore, it is necessary to prepare and deploy a testing framework to automate and homogenize the UC validation with the objective of making this framework available to extern users of the 5G-IANA platform.

This task includes also the definition of a methodology to automate and homogenize testing and validation steps. The ultimate goal is to describe a common validation methodology and technique that may be used not only within the UC deployments of the 5G-IANA project partners but also by third party experimenters wanting to use the 5G-IANA platform for experimentation purposes where different UCs and challenges may be evaluated. The present descriptions in the following sections are giving the first ideas developed within the 5G-IANA consortium. During the work of task 5.2 'nApps validation and demonstration activities', the described concepts will be elaborated and tested against the AOEP and the UC deployments and a complete test automation framework will be provided in the later deliverable D5.3 'Technical validation and demonstration of the UCs' of WP5.

A Test Automation framework is usually used to execute tests on a software. It involves:

1. The tests shall be part of the software development;
2. User actions (if any) shall be simulated programmatically.

A Test Automation framework provides different kind of tests

1. Regression tests
2. Integration tests
3. Interface conformance tests
4. Security tests

The benefits of automation testing include increased testing efficiency, faster feedback on the quality of the software, and the ability to run tests repeatedly without the risk of human error. It can also save time and money by reducing the need for manual testing, particularly in the case of repetitive or time-consuming tests.

## 4.2. The 5G-IANA Test automation framework

A test suite is a collection of test cases that are designed to cover the different kinds of tests introduced in the chapter above. It is executed in the testing execution environment of the 5G-IANA experimental platform. The 5G-IANA platform provides the capabilities to execute one or more test suites. Chapter 2 of document 'KPIs Measurement Tools - From KPI definition to KPI validation enablement' [4] of the *5G PPP Test, Measurement, and KPIs Validation Working Group* describes how a test suite and its configuration are integrated into the nApp package.

This is the responsibility of the nApp or the vertical service developers to provide the tests suites, based on the capabilities of the 5G-IANA Test automation framework. It is also the responsibility of the nApp or the vertical service developers to set up the test execution environment to execute properly the test suites.

The annex A proposes an example of a ROBOT Framework test case.

*Note: Providing a test suite for an nApp or a vertical service is not mandatory.*

## 4.3. Architecture of the 5G-IANA Test automation framework

The 5G-IANA Test automation framework is based on ROBOT Framework. This is a test automation framework characterized by:

- Open source (Apache License 2.0);
- python-based framework;
- extensible keyword-driven test automation framework;
- supporting wide range of test automation libraries and tools (e.g., Selenium, etc.).

A test suite contains:

- One configuration file containing all the required parameters to execute the test suite;
- One or more 'robot' files containing the test cases descriptions. These test cases are based on the interface provided by the nApp;
- One or more python files providing any specific extensions for the Robot framework required to execute the test suite.

Annex A proposes an example of a ROBOT Framework test case to illustrate the points above. The 5G-IANA Test automation framework is developed as an nApp. In consequence, it is designed to be dockerized and embedded into a Kubernetes pod. A 5G-IANA Test automation cluster is dedicated for nApp and vertical services testing before to be deployed. This is the 5G-IANA test environment.

## 4.4. 5G-IANA Test automation framework workflow

The 5G-IANA Test automation framework is triggered by the DevOps pipeline after the nApp or the vertical service docker image was built and published into the registry and deployed to the 5G-IANA test environment (see 'D4.1 First report on 5G-IANA nApp Toolkit and VNFs Repository development' [5], chapter 2.2.3). The figure below describes the procedures to trigger the 5G-IANA Test automation framework:

1. After publishing the nApp into the registry, the DevOps pipeline triggers the execution of 5G-IANA test automation framework;
2. The 5G-IANA test automation framework builds the list of all the tests suites to execute. If the nApp has some dependencies to another nApp, the 5G-IANA Test automation framework will execute the tests suite of each of these nApps; it should be checked whether all nApps are available in the catalogue.
3. If the test suites executions are successful, the DevOps pipeline validates the whole process. If not, the DevOps pipeline process fails.

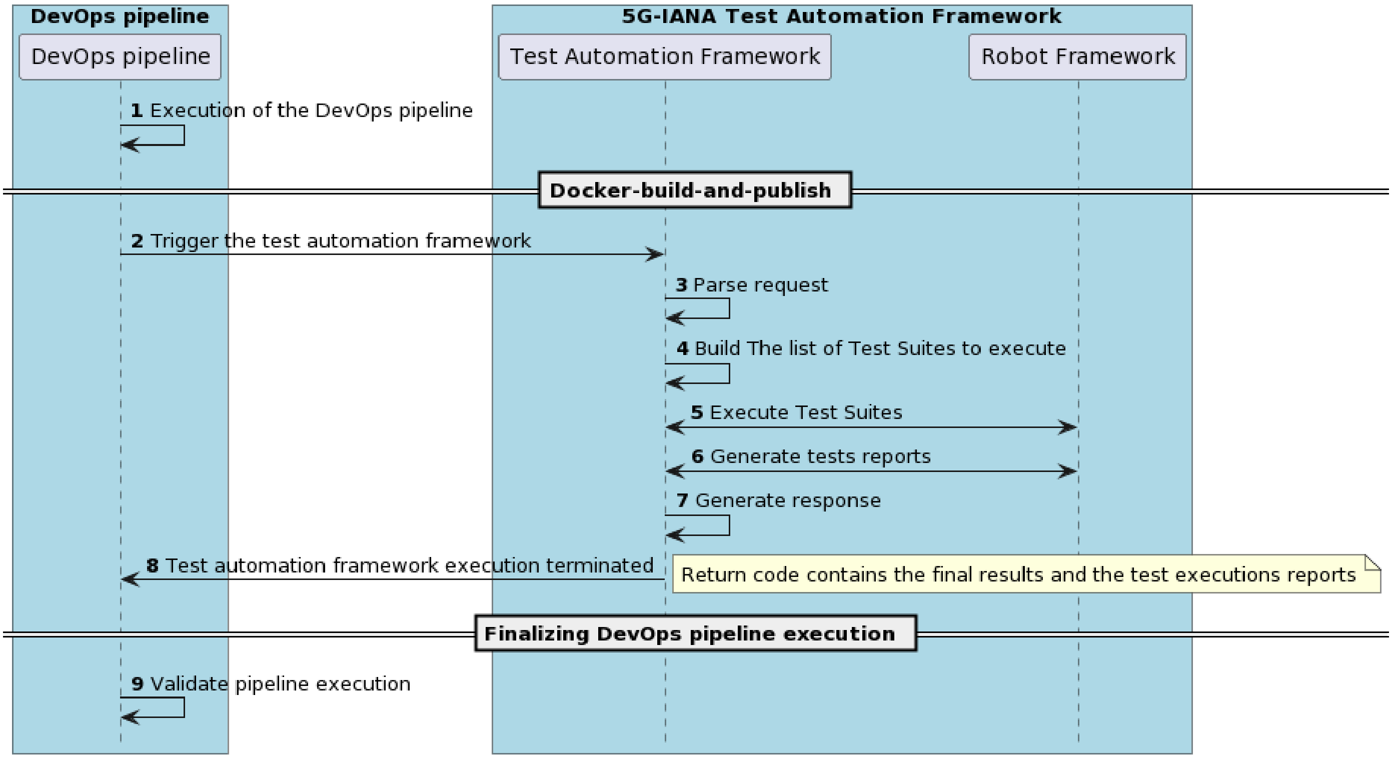


**Figure 1, 5G-IANA Test automation framework synopsis**

## 4.5. Methodology to develop a test suite

In the present chapter, the nApp to be tested (a single nApp or a UC as a single nApp) is called IUT (Implementation Under Test). The methodology is as follows:

1. Identify the set of nApp used to build the IUT.
2. Update the 5G-IANA Test automation framework configuration template file to embed the test suites to be executed (one for each nApp category).
3. Trigger the 5G-IANA Test automation framework to execute the test suites.
4. Analyse the 5G-IANA Test automation framework reports to check the test cases executions failures.
5. Repeat the process until a successful execution of all the test suites.

# 5. VALIDATION THROUGH THE TESTBED

Nokia operates a 5G on-air, latency optimized on-air testbed including MEC-Servers in the city of Ulm. For 5G-IANA, one server works as a 5G-IANA platform, while a second one was installed as a MEC-Server. The servers can be accessed by 5G-IANA partners via VPN-connections. Three antenna sites, each with 3 radio sector cells and operating on the frequency band n38 (2575-2615MHz/TDD), can be configured according to project demands. Two network slices, one for V2X (default slice) and one for eMBB are configured.

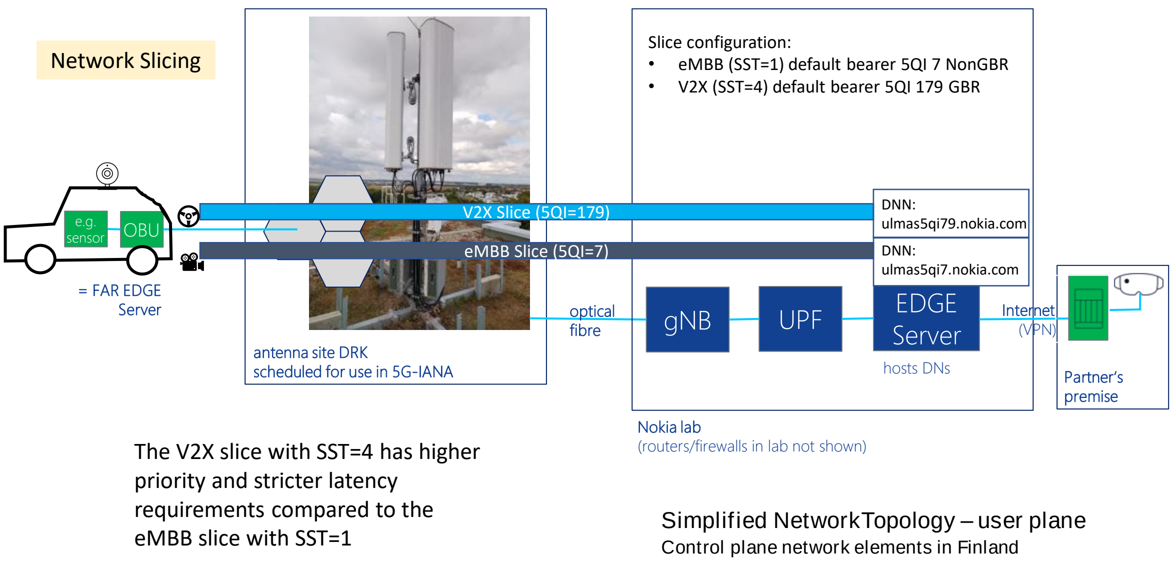


**Figure 2, Testbed overview**

The 5G-IANA UC1 to UC6 use either the V2X Slice and/or the eMBB Slice. In the 5G-IANA UC7 "Situational awareness in cross-border road tunnel", two testbeds in Ulm and Ljubljana are involved, whose EDGE-Servers are connected with a VPN-connection.

One antenna site in Ulm called "DRK" provides network coverage near a parking lot, where UC trials and demonstrations can be realized. At the parking lot, a maximum cell uplink throughput rate of 7Mbps and a maximum cell downlink throughput rate of 120Mbps is available.

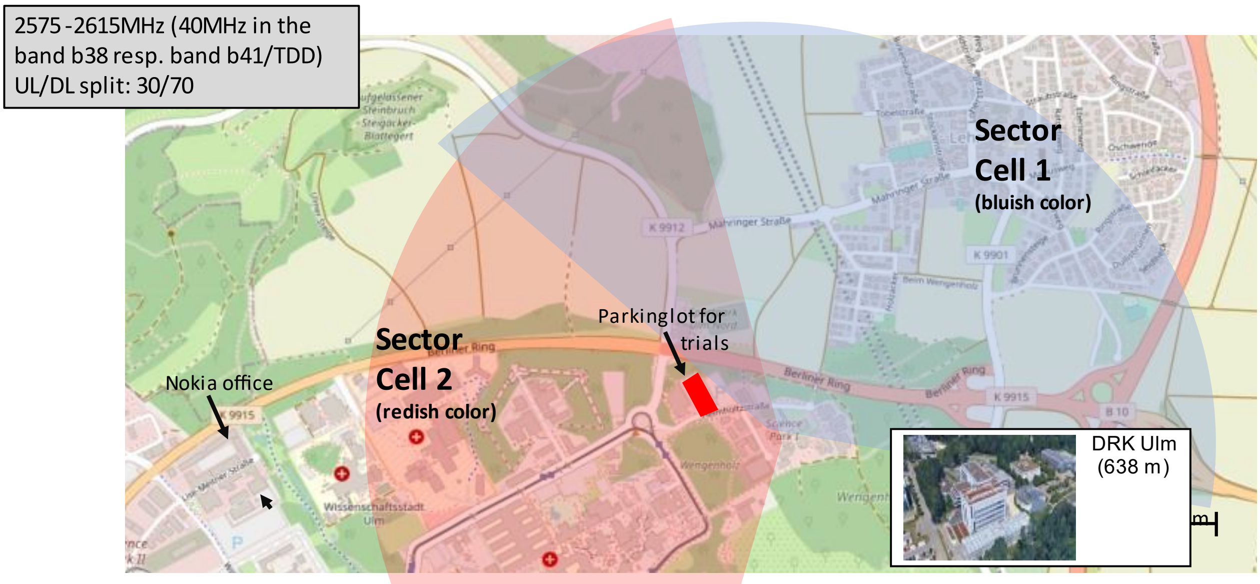


**Figure 3, Testbed trial site**

From a higher-level view, the mobile network is a transport network for 5G-IANA administrative data flows and for application data flows, which provides connectivity between the 5G-IANA components.

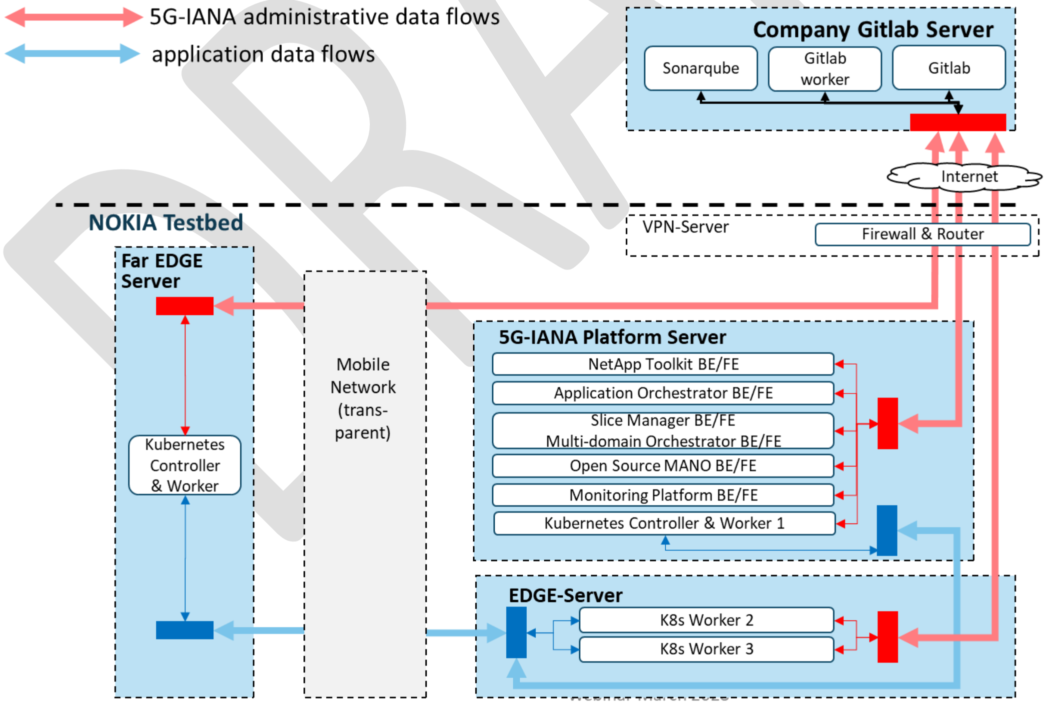


**Figure 4, Testbed data flows**

All the software that composes the 5G-IANA Platform is hosted and deployed on NOKIA's Testbed. The testbed is "behind" a firewall and in order to access it from the public internet, VPN connections are required. The computing power of the testbed is split in the core cloud and in one edge cloud.

All of the building blocks of the 5G-IANA AOEP are hosted and deployed in the core cloud of the testbed (in Figure 4 t is the 5G-IANA Platform server). Specifically,

- the nApp Toolkit that provides the nApp composition and onboarding services,
- the nApp Deployment and lifecycle Management that provides the deployment and manages the lifecycle operations of the nApp,
- the Slice Management and Resource Orchestration managing the allocation of registered programmable resources,
- the Monitoring Platform for hosting application and infrastructure telemetry,
- the Distributed ML/AI framework for 5G-specific distribution of ML models.

Both Deployment & Lifecycle manager and Slice Management and Resource Orchestration are running on top of Kubernetes. All the deployments the 5G-IANA Platform performs are inside the Kubernetes that runs in the edge and the core cloud of the testbed. For the on-vehicle deployments a flavour of Kubernetes is used, specifically Micro-K8s.

The 5G-IANA repository that hosts both the Platform's software artifacts as well as the nApp component is connected with a virtual machine inside the core cloud of the testbed. This is used to conduct the tests under the execution flow of the CI/CD pipelines that has been defined.

The edge server which is also provided for nApp deployments is connected to the NOKIA's 5G Mobile Network. While The 5G Mobile Network is a black box to the 5G-IANA Platform, the edge server is able to receive/send traffic to the 5G Network through its connectivity with the User Plane Function (N6).

In the testbed, OBUs and RSUs are deployed, which are provided and administered by 5G-IANA partners. There are two types of data routed in the testbed: In the figure above, the red arrows represent 5G-IANA administrative data flows, while the blue arrows show data exchanges of applications.

# 6. PUBLIC ACCEPTANCE VALIDATION

The public acceptance validation methodology is based on the one used in the 5G-MOBIX project [6]. In the case of 5G-MOBIX, the objective was to evaluate the acceptance for the proposed CAM use cases. They also intended to investigate how breaks in service continuity, which may occur during border-crossing, may impact on the user experience and consequently, on the acceptability towards the CAM proposal. In the case of 5G-IANA, the objective is to evaluate the acceptance of the AOEP. As the objectives and the scope of both projects are quite different, the 5G-MOBIX methodology has been significantly adapted to fit 5G-IANA.

The 5G-IANA's public acceptance validation methodology comprises three methods:

- Survey with Open Call participants.
- Survey with representative users.
- Online survey.

Five different KPI categories are considered to be measured:

- Intention to use.
- Perceived usefulness.
- Perceived ease-of-use.
- Trust.
- Reliability.

In the following subsections each of the validation methods is described, detailing the KPIs that are going to be measured on each of them.

## 6.1. Survey with Open Call participants

Open Call participants will run their automotive network applications on top of the platform provided by the 5G-IANA project. The 5G-IANA consortium will support Open Call participants to develop and integrate their innovative idea using the 5G-IANA platform. After they complete their experimentation, the Open Call participants will be asked to complete a questionnaire and answer an interview to assess the acceptance of the platform.

### 6.1.1. Questionnaire

#### *6.1.1.1. Demographic data*

The questionnaire starts collecting demographic data about the participants in the study. More specifically, the following data will be collected:

**Table 85, Demographic data collected in the survey with Open Call participants**

| Question | Options |
|---|---|
| Gender | Female |
| | Male |
| | Prefer not to say / No answer |
| Age | 18-30 years |
| | 31-40 years |
| | 41-50 years |
| | 51-60 years |
| | > 61 years |
| Sector | Service or application creation/ software development |
| | Service provider |
| | Consulting |
| | Other (specify) |
| Knowledge of 5G technology | 5-point Likert scale. |
| Knowledge of MEC technology | 5-point Likert scale. |
| Knowledge of Cloud technology | 5-point Likert scale. |
| Knowledge of software development | 5-point Likert scale. |
| Previous experience with Network Applications | 5-point Likert scale. |
| Previous participation in an Open Call or similar activity | Yes / No |

#### *6.1.1.2. ATI scale*

The questionnaire for Open Call participants, includes a set of questions that are part of the Affinity for Technology Interaction (ATI) scale, which is designed to assess a person's tendency to actively engage in intensive technology interaction, a factor that is known to affect acceptability. This is a widely used psychometric scale that evaluates a user's proneness to interact with technological artefacts [7]. It is a nineitem scale, where each item is answered in a 1 – 6 scale (1 – completely disagree; 6 – completely agree). The following items are part of the questionnaire:

1. I like to occupy myself in greater detail with technical systems.
2. I like testing the functions of new technical systems.
3. I predominantly deal with technical systems because I have to.
4. When I have a new technical system in front of me, I try it out intensively.
5. I enjoy spending time becoming acquainted with a new technical system.
6. It is enough for me that a technical system works; I don't care how or why.
7. I try to understand how a technical system exactly works.
8. It is enough for me to know the basic functions of a technical system.
9. I try to make full use of the capabilities of a technical system.

The final rating of the scale is obtained by inverting the answer to negatively worded items (3,6,8) and then computing a global mean.

#### *6.1.1.3. KPIs for user acceptance*

The KPI categories for user acceptance are based in the ones used by the 5G-MOBIX project: intention to use, perceived usefulness, perceived ease-of-use, trust and reliability. All the questions will be answered using a 5-point Likert scale.

**Table 86, KPIs for user acceptance collected in the survey with Open Call participants**

| KPI category | Question |
|---|---|
| Intention to use | Assuming I have access to 5G-IANA platform, I intend to use the 5G-IANA platform if I want to develop, test or deploy a Network Application, |
| Perceived Ease of Use | It is easy to deploy a Network Application on top of the 5G-IANA platform. |
| | Learning to use the 5G-IANA platform would be easy for me. |
| | The 5G-IANA platform requires the fewest steps possible to accomplish what I want to do with it. |
| Perceived usefulness | The 5G-IANA platform meets the needs of Network Application developers. |
| | The 5G-IANA platform facilitates the deployment of innovative automotive-related applications. |
| | The 5G-IANA platform does everything I would expect it to do. |
| Trust | Overall, I could trust the 5G-IANA platform. |

| | |
|---|---|
| | I would trust an automotive application deployed on top of the 5G-IANA platform. |
| | I would feel confident using an automotive application deployed on top of the 5G-IANA platform. |
| Reliability | I believe that the 5G-IANA platform will perform consistently under a variety of circumstances and use cases. |
| | I believe the 5G-IANA platform would be free of critical errors. |
| | I believe I could rely on the 5G-IANA platform to test and deploy Network Applications. |

### 6.1.2. Interview

In addition to the questionnaire, three questions have been chosen for specific short interviews with Open Call participants to augment the questionnaire and get additional insights:

1. What is your implication in the automotive ecosystem and the view of 5G in your organization?
2. Which are in your view the main regulatory, interoperability or standardization barriers for the acceptance and adoption of 5G-IANA's platform?
3. How can regulatory entities, policy makers and standardization bodies overcome these barriers?

## 6.2. Survey with representative users

The Open Call participants are the primary target for the user acceptance study. They are external experimenters and potential future users of the platform, so their opinion is very valuable. However, the number of Open Call participants can be low, which can diminish the significance of the study. In order to complement the survey with Open Call participants, an additional survey is planned with representative users coming from the 5G-IANA consortium. More specifically, use case developers who are not directly involved in the development of the 5G-IANA AOEP will be recruited. The recruited use case developers will complete a questionnaire based on their experience using the 5G-IANA AOEP. The recruitment of the representative users will be done in the context of task T5.3 'Public acceptance' and the target number of participants will be at least 30.

The questionnaire with representative users will include the same demographic questions as in the questionnaire with Open Call participants (see Table 85) excepting the question about previous participation in an Open Call or similar activity. The ATI scale questions will also be part of the questionnaire. Regarding the KPI questions, all the questions excepting "Intention to use" will be asked.

## 6.3. Online survey

Given the difficulty in engaging a large number of Open Call participants, an additional approach has been devised to get insights from potential end-users of the 5G-IANA AOEP. The approach consists of an online survey, in which each participant watches a video that explains the concept and approach of 5G-IANA AOEP. An introductory text will accompany the video summarising the objectives of the 5G-IANA AOEP and the purpose of the study. After watching the video, the participants complete a questionnaire.

As it is very challenging to engage people in conducting a lengthy online survey, the questionnaire will be minimised as much as possible, keeping only the most relevant questions. The participants will be motivated with a raffle of either an economic prize or a 5G-IANA "communication kit", consisting of a series of web articles and social media posts to promote the SME or startup of the winner using the 5G-IANA communication channels.

The questionnaire will contain a set of questions to collect demographic data of the participants, and then a set of questions to measure the user acceptance. Even if it could be interesting for the study, the ATI scale questions have been discarded for the sake of simplifying and minimising as much as possible the questionnaire.

The questionnaire will also be distributed among the audience of a webinar dedicated to explaining the technical approach of the 5G-IANA AOEP. Other dissemination options for the survey will be studied under the framework of task T5.3 'Public acceptance' in liaison with WP7.

### 6.3.1. Demographic data

The online questionnaire will collect the essential demographic data to interpret the KPI results:

**Table 87, Demographic data collected in the online survey**

| Question | Options |
|---|---|
| Gender | Female |
| | Male |
| | Prefer not to say / No answer |
| Age | 18-30 years |
| | 31-40 years |
| | 41-50 years |

| | |
|---|---|
| | 51-60 years |
| | > 61 years |
| Sector | Service or application creation |
| | Service provider |
| | Consulting |
| | Other (specify) |
| Previous knowledge of Network Applications | 5-point Likert scale. |

### 6.3.2. KPI for user acceptance

The KPI selected for the online survey is perceived usefulness. This metric is defined as the extent to which the individual believes that using a system will enhance her/his job performance. People form perceived usefulness judgments by comparing what a software product is capable of doing with what they need to get done. Perceptions of usefulness based on user exposure to pre-prototype requirements specifications will be highly predictive of similar perceptions taken after significant hands-on experience with a working system having those specifications [8]. Thus, it is not necessary to experiment with a system to assess its usefulness. However, other user acceptance metrics like "perceived ease of use" require significant hands-on experience with a working system, so they are not suitable for an online survey with participants that have not used the 5G-IANA platform.

Therefore, for the online survey a single KPI category will be used, "perceived usefulness", that literature backs up as measurable by people without hands-on experience with the working system [8]. This way we can reach a broader audience as we are not limited to experimenters. The questions for measuring the "perceived usefulness" in the online survey are listed below and will be answered with a 5-point Likert scale.

**Table 88, KPIs for user acceptance collected in the online survey**

| KPI category | Question |
|---|---|
| Perceived usefulness | Using an open experimental platform on top of which third party experimenters can develop, deploy and test their automotive-related services based on Network Applications, would improve the productivity of these third parties. |
| | I find it useful to provide a Network Applications starter-kit with baseline examples of different categories of Network Applications that third parties can re-use to develop their own vertical services/Network Applications. |

| | |
|---|---|
| | I believe that an Automotive Open Experimental Platform (AOEP) composed by a whole set of hardware and software resources that provides the computational and communication/transport infrastructure as well as the management and orchestration components, coupled with an enhanced Network Application Toolkit tailored to the Automotive sector, can simplify the design an onboarding of new Network Applications. |

# REFERENCES


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# ANNEX A: AN EXAMPLE OF ROBOT FRAMEWORK TEST CASE

This example is extracted from the ETSI MEC Test Conformance API project. It contains three sections:

1. The Settings section. This section contains reference to the test case configuration information, the test case parameter values and libraries required to execute the test case;
2. The Test Cases section. This section is the keywords-oriented test description;
3. The Keywords section. This section provides some test case specific keyword.

An additional section named Comments can be added for custom use, but it is ignored by the ROBOT Framework.

```
*** Settings ***

Documentation
...    A test suite for validating Radio Node Location Lookup (RLOCLOOK) operations.

Resource    ../../../pics.txt
Resource    ../../../GenericKeywords.robot
Resource    environment/variables.txt
Library     REST    ${SCHEMA}://${HOST}:${PORT}    ssl_verify=false
Library     OperatingSystem

Default Tags    TC_MEC_SRV_RLOCLOOK


*** Test Cases ***

TC_MEC_MEC013_SRV_RLOCLOOK_001_OK
    [Documentation]
    ...    Check that the IUT responds with the list of radio nodes currently associated with the MEC host and the location of each radio node
    ...    when queried by a MEC Application
    ...
    ...    Reference    ETSI GS MEC 013 V2.1.1, clause 7.3.7
    ...    OpenAPI    https://forge.etsi.org/gitlab/mec/gs013-location-api/blob/master/LocationAPI.yaml#/definitions/AccessPointList

    [Tags]    PIC_MEC_PLAT    PIC_SERVICES    INCLUDE_UNDEFINED_SCHEMAS
    Get the access points list        ${ZONE_ID}
    Check HTTP Response Status Code Is    200
    Check HTTP Response Body Json Schema Is    AccessPointList
    Should Be Equal As Strings    ${response['body']['accessPointList']['zoneId']}    ${ZONE_ID}


TC_MEC_MEC013_SRV_RLOCLOOK_001_NF
    [Documentation]
    ...    Check that the IUT responds with an error when
    ...    a request for an unknown URI is sent by a MEC Application
    ...
    ...    Reference    ETSI GS MEC 013 V2.1.1, clause 7.3.7

    [Tags]    PIC_MEC_PLAT    PIC_SERVICES
    Get the access points list        ${NON_EXISTENT_ZONE_ID}
    Check HTTP Response Status Code Is    404


*** Keywords ***
Get the access points list
    [Arguments]    ${zoneId}
    Set Headers    {"Accept":"application/json"}
    Set Headers    {"Authorization":"${TOKEN}"}
    Get    ${apiRoot}/${apiName}/${apiVersion}/queries/zones/${zoneId}/accessPoints
    ${output}=    Output    response
    Set Suite Variable    ${response}    ${output}
```

**Figure 5, ROBOT framework example**