H2020 5GASP Project

Grant No. 101016448

Initial Report for the Network Application certification testing

Abstract

This deliverable defines the certification process and all tests used to fulfil the certification of each Network Application involved in the project. It encompasses three primary outcomes: further elaboration on the Network Application's certification process, further definition of the tests used in this process and definition of the tailor-made tests that will be used to further test and validate each Network Application. It will cover the initial results of certification of the specific Network Applications participating in the project and some preliminary certification results.

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Acronyms

3GPP	3rd Generation Partnership Project
5GASP	5G Application & Services experimentation and certification Platform
5GS	5G System
AF	Assured Forwarding
API	Application Programming Interface
BER	Bit Error Rate
BW	bandwidth
CAM	Cooperative Awareness Messages
CI/CD	Continuous Integration and Continuous Deployment
CIR	Container Image Registry
CISM	Container Infrastructure Service Management
C-ITS	Cooperative Intelligent Transport Systems
CN	Core Network
CNF	Cloud-native Network Function
CP	Control Plane
CPU	Central Processing Unit
CU	Centralized Unit
DDoS	Distributed denial of service
IMHO	Efficient MEC Handover
E2E	End-to-End
FIDEGAD	Fire detection and ground assistance using drones
gNB	Next Generation Node B
GPU	Graphics Processing Unit
ICMP	Internet Control Message Protocol
IETF	Internet Engineering Task Force
IOPS	Isolated Operations for Public Safety
IP	Internet Protocol
KPI	Key Performance Indicator
kubectl	Command line tool
MEC	Multi-access Edge Computing
MANO	Management and Orchestration
NEF	Network Exposure Function
NF	Network Function
NFV	Network Functions Virtualization
NFVO	Network Function Virtualization Orchestrator
NODS	Network Application Onboarding and Deployment Service
NS	Network Service
NSD	Network Service Descriptor
OA&M	Operations, Administration and Maintenance

OSM	OpenSourceMANO
OSRM	Open Source Routing Machine
PLMN	Public Land Mobile Network
PLR	Packet Loss Ratio
PPDR	Public Protection and Disaster Relief
qMON	Quality Monitoring System
QoS	Quality of Services
RAN	Radio Access Network
REST	Representational State Transfer
RSSI	Received Signal Strength Indicator
RTT	Round-trip time
SBA	Service Based Architecture
SQL	Structured Query Language
SSH	Secure Shell Protocol
SSL	Secure Sockets Layer
SFTP	Secure File Transfer Protocol
TLS	Transport Layer Security
UE	User Equipment
UoP	UoPatras
UP	User Plane
UPF	User Plane Function
VAL	Vertical Application Layer
VIM	Virtualized Infrastructure Manager
VMs	Virtual Machines
VNFM	Virtual Network Functions Manager
VNF	Virtual Network Function
vOBU	Virtual On-Board Unit
VLAN	Virtual Local Area Network
VNFD	Virtual Network Function Descriptor
VPN	Virtual Private Network
vRSU	Virtual RoadSide Unit
WP	Work Package
DENM	Decentralized Environmental Notification Message

Definitions

This document contains specific terms to identify elements and functions that are considered to be mandatory, strongly recommended or optional. These terms have been adopted for use similar to that in Internet Engineering Task Force (IETF) RFC2119 and have the following definitions:

- **MUST** This word, or the terms "REQUIRED" or "SHALL", mean that the definition is an absolute requirement of the specification.
- **MUST NOT** This phrase, or the phrase "SHALL NOT", mean that the definition is an absolute prohibition of the specification.
- **SHOULD** This word, or the adjective "RECOMMENDED", mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.
- **SHOULD NOT** This phrase, or the phrase "NOT RECOMMENDED" mean that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
- **MAY** This word, or the adjective "OPTIONAL", mean that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein, an implementation that does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides).

1 Introduction

1.1 Objectives of this document

D5.1[1] described all the efforts made to pave the way for achieving a Continuous Integration and Continuous Deployment (CI/CD) scenario in 5G Application & Services experimentation and certification Platform (5GASP), introducing the methodologies of the 5GASP Validation Process. D5.2[2], on the other hand, described the Network Application's onboarding and integration process, including the Application Programming Interface (API) reference manuals and the Network Service (NS) descriptors of the targeted Network Applications. Lastly, D5.3[3] presented a collection of 5GASP test cases and further elaborated on the testing methodologies used to validate Network Applications.

This document presents an expansion and concretization of the work presented in the deliverables mentioned above, detailing how the previous Work Package (WP) 5 outcomes are being used to fully validate and certify a Network Application. Thus, this document aims to further define the certification process and all tests used to fulfil the certification of a Network Application.

Besides the certification-mandatory tests, as described in D5.2[2] and D5.3[3], Network Application owners may also onboard Network Application-specific tests. These tests are not fully considered for the certification of a Network Application since they are created by the Network Application developers, which may lead to a bias. Although, these tests are crucial for the Network Application owners to validate the functionality and behaviour of their Network Application, thus being addressed in this document.

To summarize, this deliverable encompasses three primary outcomes: (i) further elaboration on the Network Application's certification process, (ii) further definition of the tests used in this process, and (iii) definition of the tailor-made tests that will be used to further test and validate each Network Application.

1.2 Approach and Methodology

This document mainly aims to further elaborate on the 5GASP certification mechanisms. To better understand the output of this deliverable, the reader should be fully aware of the concepts and methodologies introduced in previous WP5 deliverables.

Previously, D5.1[1] introduced the testing methodologies that shall be used to validate a Network Application. Besides, it also introduced the 5GASP's Validation Service, along with a detailed description of its components, which was then further elaborated in D5.2[2]. These two deliverables introduced the architecture and the features of the Validation Service that will be used to certify a Network Application.

D5.2[2] also addressed the testing APIs and all the software tools present in each testbed, addressing the possible ways to achieve a Validation Service distributed between all testbeds, ergo, paving the path towards integration solutions that ultimately enable the execution of testing and validation pipelines in different testbeds. Thus, this deliverable ultimately demonstrated how the Validation Service, presented in D5.1[1], could be deployed in a distributed paradigm that would enable the execution of validation pipelines across all 5GASP's Testbeds.

Finally, D5.3[3] introduced the test plan that shall be used to certify a Network Application. This deliverable defined some global tests that could be used to validate any Network Application and later addressed the specification of vertical-specific tests and the Key Performance Indicators (KPIs) that should be measured.

This document is a follow-up to all the previously described deliverables.

Being part of Task 5.3 - "Certification Guidelines", this document tries to close the loop of the Certification Process, introducing new achievements in regard to this operation and further elaborating its workflow. To certify a Network Application, besides the defined global tests, Network Application developers may choose to onboard their own tests and validate the behaviour and functionality of their Network Application. Although these tests may be seen as biased, since they were developed by the same developer as the Network Application, the certification process can readily divulge the results of their execution and make available all the log and report files collected during the testing and validation phase. This would allow a third-party entity to know precisely which tests were executed to validate a Network Application, thus increasing the trust in it.

The 5GASP consortium considers these developer-defined tests a crucial element of the Certification process. Consequently, this document analyses each Network Application and lists a collection of tests that can be used to validate its functionality and behavior.

1.3 Document Structure

This document is composed of eight chapters, the first chapter, Introduction, presents the objectives of this document along with the approach and methodology.

In Chapter 2, Network Applications Certification Definitions, presents all the definitions that shall be used to certify each 5GASP consortium Network Application. Those definitions are divided into four main categories: P0 (mandatory), P1 (recommended), P2 (optional), and P3 (conditional).

Chapter 3 presents Network Applications Certification Testing, including description of: 5G readiness testing axis, security & privacy testing axis, performance & scalability testing axis, availability & continuity testing axis, relationship between 5GASP's Network Application

certification tests and 5GASP's validation tests and also the certification report according to the defined testing axis.

In Chapter 4, Network Applications Certification Test Cases, is presented a list of test cases that shall be part of the 5GASP certification process, divided by each testing scope: 5G readiness axis test cases, security & privacy axis test cases, performance & scalability axis test cases and availability & continuity axis test cases.

Chapter 5 presents the status of the 5GASP certification process, the status on the certification test cases implementation and next steps on 5GASP certification process.

Chapter 6 is composed of two main sections. Subsection 6.1 depicts the preliminary results of the testing that has been already performed in all the testbeds of the project: Murcia, Aveiro, Bristol, Patras, Bucharest and Ljubljana sites. Subsection 6.2 presents the initial test plans that have been designed for each of the eleven Network Applications involved in the project (Network Application 1: Virtual On-Board Unit provisioning Network Application (vOBU), Network Application 2: Virtual RoadSide Unit provisioning Network Application (vRSU), Network Application 3: ITS station Network Application, Network Application 4: Multi-domain Migration Network Application, Network Application 5: Vehicle-to-Cloud (V2C) Real-Time Communication Network Application, Network Application 6: Remote Human Driving Network Application - Teleoperation for assisting vehicles in complex situations, Network Application 7: Efficient MEC handover Network Application, Network Application 8: PrivacyAnalyzer Network Application, Network Application 9: 5G Isolated Operation for Public Safety Network Application (5G IOPS Network Application), Network Application 10: Vehicle Route Optimizer Network Application, Network Application 11: Fire detection and ground assistance using drones (FIDEGAD)).

Chapter 7 presents some preliminary certification results.

Finally, Chapter 8 provides conclusions.

2 Network Applications Certification Definitions

5GASP's Certification Process aims to provide the efficient and meaningful means and methods required to measure the ability of a Network Application to perform with the expected quality and performance standards, inherent both from the application's scope and the target deployment environment.

On the process side, the certification testing is thoroughly defined in D6.2[4], illustrating an End-to-End (E2E) workflow along with the employed stakeholders. On the business side, driven by the effort to investigate and incorporate certification aspects with significant technical scope and match market requirements, the project relied on the definitions presented in Subsection 3.1 of D5.3[3] to steer the development of 5GASP's Certification Process. Furthermore, based on these definitions, we elaborate on the priority of addressing each definition during the 5GASP Network Applications Certification Testing Process.

2.1 Certification Definitions

To prioritize each Network Application certification definition during the 5GASP's Network Application validation phase, we defined four test priority levels: P0 (mandatory), P1 (recommended), P2 (optional), and P3 (conditional). The definitions considered to have a priority level of 0 (P0) must be addressed by the Network Applications in order to obtain the 5GASP certification, being the baseline for the certification of a Network Application. *Table 1* brings forth the definitions previously presented in D5.3[3], along with their assigned priority for testing.

Table 1 - Network Applications Certification Definitions and Test Priorities

Definition ID	Test Priority	Description	Testable
1	P1	Should deliver services to 5G Verticals.	No
2	P2	May consist of both software and hardware parts.	No
3	P1	Must embrace the Service Based Architecture (SBA) paradigm.	No
4	P0	Should follow the Network Functions Virtualization (NFV) model (Network Service Descriptor (NSD)/ Virtual Network Function Descriptor (VNFD) (YANG or TOSCA)).	No
5	P2	May expose APIs to be consumed by other service consumers. The exposed APIs should be delivered in an Open API model and may follow	Yes

		the 3rd Generation Partnership Project (3GPP) recommended APIs for applications.	
6	P2	A Network Application may be part of one or more vertical application services.	Yes
7	P3	One or more services of the Network Application may be attached to one or more 5G User Plane Function (UPF) data paths.	Yes
8	P2	May be part of one or more 5G slices. The slices may be shared or not.	Yes
9	P2	Part of a Network Application may reside at the User Equipment (UE) side. The part of the UE side may interact with a Network Application service that resides within the domain network. The UE part may follow the definition of the Vertical Application Layer (VAL) client of 3GPP.	Yes
10	P2	May be part of the 5G Core. In such case, then it must follow the 3GPP standards.	No
11	P3	May interact with the 5G System (5GS) by consuming 5GS's APIs, if the 5GS allows. When interacting with the 5GS, it must support relevant 3GPP standards. Such interactions may include location services, Quality of Services (QoS) management, Assured Forwarding (AF) traffic.	Yes
12	P2	May support service continuity by minimizing service interruption when transferring application context.	Yes
13	P2	Software parts should be deployed either in a virtualized or containerized manner.	Yes
14	P3	May have resource and network requirements in terms of hardware, memory, Graphics Processing Unit (GPU), Central Processing Unit (CPU), availability, etc.	No
15	P2	May have placement requirements (e.g. edge, region, core, etc.). Additionally, a network latency KPI must be specified by the Network Application when requesting a slice by the 5GS.	Yes
16	P2	May consume monitoring and telemetry data from the 5G System. Such data from the 5GS should be consumed by functions like the Network Data Analytics Function (NWDAF).	No

17	P2	May interact with the Virtualized Infrastructure Manager (VIM)/Container Infrastructure Service Management (CISM) of the domain, if this is not restricted.	Yes
18	P3	May interact with the Service or NFVO of the domain if this is not restricted.	Yes
19	P0	Should follow relevant 3GPP security definitions and recommendations	Yes

From *Table 1*, it is clear that all Network Applications must address definitions 4 and 19 to obtain the 5GASP's certification.

Definition 4 states that any Network Application should follow the NFV model, which will be validated by statically analyzing the syntax, semantics, and references of the NSDs and VNFDs uploaded to the 5GASP framework. These aspects are validated during the onboarding of a Network Application to the 5GASP Network Application Onboarding and Deployment Service (NODS). If the Network Application does not comply with Definition 4, it will not be orchestrated in one of the 5GASP's testbeds.

Definition 19, on the other hand, states that a Network Application should follow relevant 3GPP security definitions and recommendations. All Network Applications must be compliant with this definition, proving there are secure and will not pose any risk to the operators that choose to onboard such Network Applications.

Once the mandatory definitions are addressed, it is up to Network Application developers and experimenters to determine if their solutions are compliant with other definitions. These additional formulations are considered as certification expanded criteria and comprise a set of optional definitions that can be considered in the certification process and be later reflected in the 5GASP certification of the Network Application.

2.2 5GASP's Network Applications Certification Definitions

From what was previously stated, to achieve 5GASP's Certification stamp, all project's Network Applications must comply with definitions 4 and 19. However, all 5GASP Network Applications can also address some recommended (P1), optional (P2), and conditional (P3) definitions. Thus, these Network Applications must not refrain from doing so.

Even though some 5GASP Network Applications are still not ready to comply with such definitions, it is expected that during the remaining duration of the project, all Network Applications will be compliant with some of the P1, P2, and P3 definitions. Such expectations are showcased in *Table 2*, which comprises an "Optional Definitions" column showcasing all definitions though which each Network Application will be certified.

Table 2 5GASP's Network Applications mandatory and optional definitions for certification

Network Application ID: Network Application name	Mandatory definitions	Optional definitions
1: Virtual On-Board Unit provisioning Network Application (vOBU)	4, 19	2, 5, 11, 13, 15, 18
2: Virtual RoadSide Unit provisioning Network Application (vRSU)	4, 19	2, 13, 14, 15
3: C-ITS station Network Application	4, 19	2, 13, 14, 15
4: Multi-domain Migration Network Application	4, 19	2, 5, 11, 13, 15, 18
5: Vehicle-to-Cloud (V2C) Real-Time Communication Network Application	4, 19	6, 8, 11, 14
6: Remote Human Driving Network Application - Teleoperation for assisting vehicles in complex situations	4, 19	6, 8, 11, 14
7: Efficient MEC handover Network Application	4, 19	2, 5, 11
8: Privacy Analyzer Network Application	4, 19	6, 9, 14
9: 5G Isolated Operation for Public Safety Network Application (5G IOPS Network Application)	4, 19	2, 6, 12, 13, 14
10: Vehicle Route Optimizer Network Application	4, 19	8, 11, 12, 13, 15
11: Fire detection and ground assistance using drones (FIDEGAD)	4, 19	2, 7, 13

3 Network Applications Certification Testing

3.1 Network Applications Certification Testing Scope

To certify a Network Application, 5GASP relies on a vast collection of tests that were defined based on the previously presented certification definitions. Given the different scopes of the certification definitions, we opted to define a multi-dimensional certification process. Thus, several testing scopes were considered to address the different certification methodologies. Moreover, the existence of different testing scopes heavily influences 5GASP's certification process since each Network Application will be given a certification grade according to each testing scope.

Based on the previously presented certification definitions, we defined the following testing scopes/axis: (i) 5G Readiness Testing, (ii) Security & Privacy Testing, (iii) Performance & Scalability Testing, and (iv) Availability & Continuity Testing. Given that all Network Applications must comply with definitions 4 and 19, when considering these testing scopes, we can affirm that all Network Applications must fulfil the 5G Readiness and the Security & Privacy testing scopes.

Adding more axes to the certification process is still under discussion and will be provided in future deliverables in WP6.

3.1.1 5G Readiness Testing Axis

This axis has tests oriented to determine the readiness of the Network Applications for the 5G Network, from interaction, control, and communication aspects.

The tests defined in this axis shall verify the ability of the Network Application to communicate, interact and use the Network Exposure Function (NEF) interface and other possible 5GS components during the operation of the Network Application.

3.1.2 Security & Privacy Testing Axis

This axis verifies the Network Applications' security by defining a group of security tests aligned to the consortium's former certification definition related to the 3GPP inherited security recommendations, common penetration testing and basic NFV segmentation.

This axis shall comprise all the necessary tests to determine the security and privacy levels of the Network Application.

3.1.3 Performance & Scalability Testing Axis

This axis evaluates the ability of the Network Application to maintain performance and resource scaling, regarding the provided expected KPIs, for different traffic types, usage, long-term functionality, processing, bandwidth, latency, and Bit Error Rate (BER) under an E2E scenario.

3.1.4 Availability & Continuity Testing Axis

The availability and continuity axis evaluate the ability of the Network Application to sustain service over time regarding the provided KPIs, under different stress scenarios, like transmission impairments, long-term burn, service request denial, or downgrade from 5GS.

The tests defined under this axis will measure the ability of the Network Application to overcome the exceptional circumstances of the 5G network.

3.2 Relationship Between 5GASP'S Network Application Certification Tests and 5GASP's Validation Tests

D5.1[1] coined the terms pre-defined tests and developer-defined tests for the tests performed during a Network Application validation. Pre-defined tests are already onboarded in 5GASP's ecosystem, enabling all Network Application developers to rely on them to validate their Network Applications. Furthermore, these tests' implementation is static, meaning all Network Applications that wish to rely on them will be tested the same way. On the other hand, developer-defined tests are developed by the Network Application owners and then onboarded and executed by the 5GASP's Validation Service. This means that each of these tests has a custom implementation. For instance, different developers may design tests to validate the authentication of their Network Application with the NEF interface of the 5GS. All these tests may be different from one another, which means that a *Network Application A* may pass a *NEF Test A*, but fail a *NEF Test B*, developed to validate *Network Application B*, which can pass it.

Since the Network Application certification process should entail the same tests to certify different Network Applications, all certification-related tests are defined as pre-defined tests. However, Network Application developer can/should also define their own tests, to verify and measure different aspects, which are not included in the previously defined testing certification axes. This enables the developers to show more sustainability and durability of their Network Applications, besides the ability to identify the hidden weaknesses and potential problems earlier.

3.3 Certification Report According to the Defined Testing Axis

The final certification report should depict the evaluation of the Network Application according to each testing axis and show the minimum certification requirements as a spider/radar graph. *Figure 1* showcases an example of this graph.

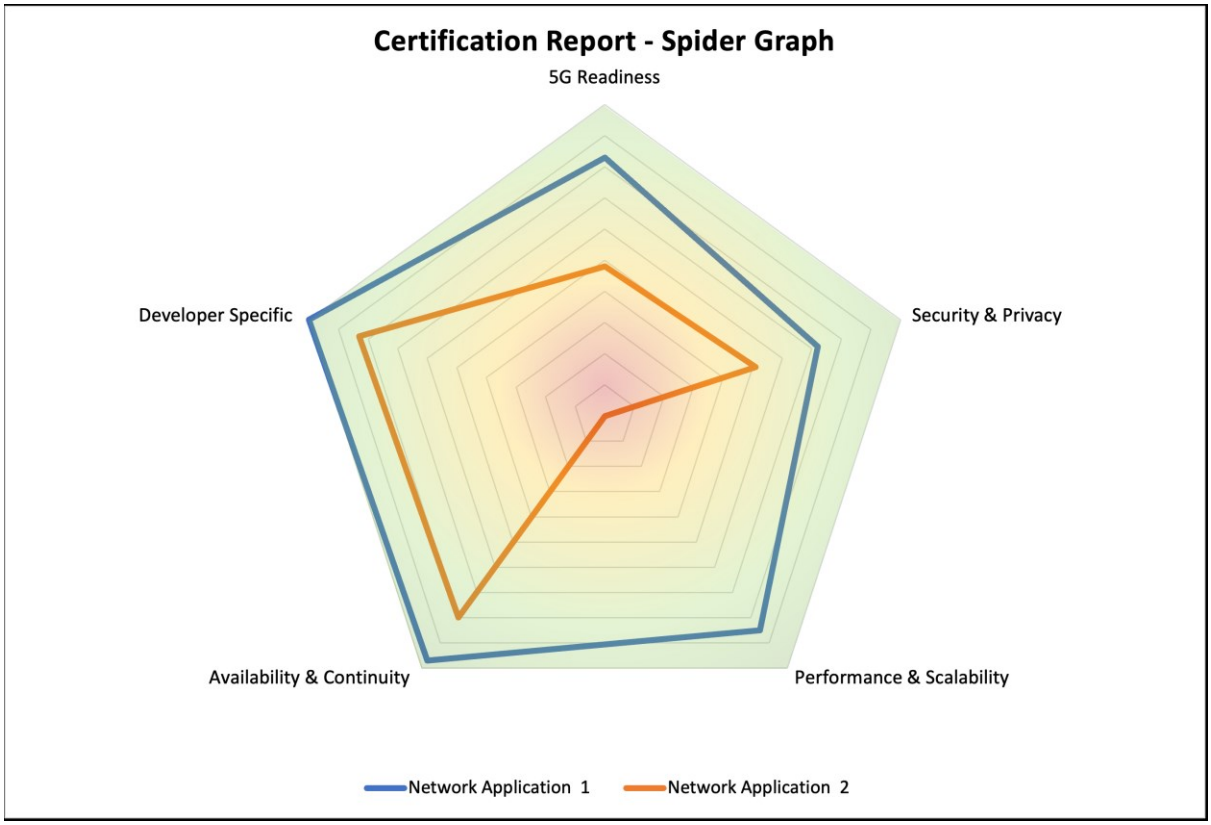


Figure 1 Certification Spider Graph - Example

4 Network Applications Certification Test Cases

Based on the Network Application certification definitions and on the different defined certification testing scopes, we can now define various test cases to evaluate the Network Applications compliance with 5GASP's Certification. Having defined various testing scopes, it comes naturally the definition of test cases to evaluate each scope. Thus, this section presents a list of test cases that shall be part of the 5GASP certification process, divided by each testing scope.

4.1 5G Readiness Axis Test Cases

Table 3 5GASP's 5G Readiness Test Cases

Certification Definition ID	Test Case ID	Test Case	Description
11	def11.5G.1	Authentication with 5GS	This test will validate the authentication and authorization of a Network Application to use 5GS resources
11	def11.5G.2	Acquisition of UE location	This test will validate that a Network Application is able to retrieve an indicative UE location
11	def11.5G.3	Acquisition of UE handover event	This test will validate that a Network Application is able to subscribe and eventually retrieve information about an indicative UE handover event (servicing cell switch)
11	def11.5G.4	Acquisition of UE Received Signal Strength Indicator (RSSI) information	This test will validate that a Network Application is able to retrieve indicative information about RSSI
11	def11.5G.5	Acquisition of UE path loss	This test will validate that a Network Application is able to retrieve indicative information about the UE RSSI subtracted from the respective radio node transmitted (path loss)
11	def11.5G.6	Acquisition of serving cell information	This test will validate that a Network Application is able to retrieve indicative information about the serving radio node (cell)
11	def11.5G.7	Acquisition of QoS sustainability	This test will validate that a Network Application is able to subscribe and eventually retrieve information about a QoS compromised event

4.2 Security & Privacy Axis Test Cases

Table 4 Security & Privacy Axis Test Cases

Certification Definition ID	Test Case ID	Test Case	Description
19	def19.Sec.1	Network Application Package Integrity	Validate package signature, to avoid the onboarding of unauthorized or modified copies of the given Network Application
19	def19.Sec.2	VNFs should use a security-group offered by testbed	Validate if the Network Application's VNFs use a testbed available security-group
19	def19.Sec.3	Openstack Port Security	Validate if the Network Application's VNFs have the Port Security enabled, when deployed in Openstack
19	def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs	Validate if the Network Application's VNFs offered APIs are protected with SSL
19	def19.Sec.5	Secure Secure Shell Protocol (SSH) Credentials	Validate if the Network Application's VNFs SSH credentials are not easily discovered using a brute-force attack
19	def19.Sec.6	Protected/ Encrypted Interfaces	Validate if the Network Application's VNFs offer all functionalities though protected/encrypted access protocols
19	def19.Sec.7	Open Ports	Validate if the Network Application's open ports are the ones required for the normal operation of the Network Application (only applied to Virtual Machines (VMs))
19	def19.Sec.8	SSH Server Security	Validate if the Network Application's exposed SSH Servers does not suffer from weak key/encryption algorithms (only applied to VMs)
19	def19.Sec.9	NEF Authentication	Validate if a Network Application is able to authenticate with the NEF before making any requests

4.3 Performance & Scalability Axis Test Cases

Table 5 5GASP's Performance & Scalability Test Cases

Certification Definition ID	Test Case ID	Test Case	Description
14	def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Verify if the Network Application does comply with the minimal download/ upload IP throughput and latency performance required for proper operation with single UE in E2E deployment.
14	def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	Verify if the Network Application does comply with the minimal download/ upload IP throughput and Latency performance required for proper operation with multiple UE in E2E deployment.
14	def14.Perf.3	Radio Access Network (RAN) monitoring, single UE	Validate Network Application operation on a single UE E2E deployment under certain RAN conditions using monitoring Information from the testbed.
14	def14.Perf.4	RAN monitoring, multiple UE	Validate Network Application operation on a multiple UE E2E deployment under certain RAN conditions using monitoring Information from the testbed.
14	def14.Perf.5	NEF signalling performance - response time	Validate by measuring NEF API response time.
14	def14.Perf.6	NEF signalling performance - requests per second	Validate by measuring how many requests the NEF API can serve per second.
14	def14.Perf.7	NEF signalling performance - maximum number of connections	Validate by measuring maximum number of simultaneous connections established to the NEF API.

14	def14.Perf.8	Network Application - web performance (static page)	Validate Network Application performance by extracting download/upload and net/gross speed from bytes and time.
14	def14.Perf.9	Network Application - API performance - response time	Validate by measuring Network Application API response time.
14	def14.Perf.10	Network Application - API performance - requests per second	Validate by measuring how many requests the Network Application API can serve per second.
14	def14.Perf.11	Network Application - API performance - maximum number of connections	Validate by measuring maximum number of simultaneous connections established to the Network Application.
14	def14.Perf.12	Network Application - IP Round-trip time (RTT)	Validate that Network Application replies to the Internet Control Message Protocol (ICMP) requests and not exceeding the configured value.
14	def14.Perf.13	Network Application - IP Traceroute	Validate that number of hops to the target does not exceed defined value by using ICMP request/response.

4.4 Availability & Continuity Axis Test Cases

Table 6 5GASP's Availability & Continuity Test Cases

Certification Definition ID	Test Case ID	Test Case	Description
12	def12.AvailCont.1	Network Application continues its proper functioning after restricted bandwidth scenario	A network application must rely on Server - Client concept and be container-based (UoPatras (UoP) testbed). The server-side component is deployed in a separate cluster than the client-side. Connectivity among them is achieved via 5G. After some time, a bandwidth (BW) restriction is enforced at the client-side host for a specified amount of time.

12	def12.AvailCont.2	Network Application continues its proper functioning after an introduced delay scenario	A network application must rely on Server - Client concept and be container-based (UoP testbed). The server-side component is deployed in a separate cluster than the client-side. Connectivity among them is achieved via 5G. After some time, specific delay is enforced at the client-side host for a specified amount of time.
12	def12.AvailCont.3	Network Application continues its proper functioning after an introduced packet loss scenario	A network application must rely on Server - Client concept and be container-based (UoP testbed). The server-side component is deployed in a separate cluster than the client-side. Connectivity among them is achieved via 5G. After some time, specific packet loss percentage is enforced at the client-side host for a specified amount of time.
12	def12.AvailCont.4	Network Application continues its proper functioning after an introduced packet corruption scenario	A network application must rely on Server - Client concept and be container-based (UoP testbed). The server-side component is deployed in a separate cluster than the client-side. Connectivity among them is achieved via 5G. After some time, specific packet error rate percentage is enforced at the client-side host for a specified amount of time.
12	def12.AvailCont.5	Network Application continues its proper functioning after an introduced total disruption of communication scenario	A network application must rely on Server - Client concept and be container-based (UoP testbed). The server-side component is deployed in a separate cluster than the client-side. Connectivity among them is achieved via 5G. After some time, communication is totally disrupted between the client - server for a specified amount of time.

5 Status of the 5GASP Certification Process

The status of the certification process can be observed in *Table 7*.

Table 7 The status of the certification process

Task	WP	Status	Next steps
Certification Workflow	WP6 task	Defined in WP6	Updates upon need - if any - will be reflected in WP6 deliverables.
Test Axes for Certification evaluation	WP6 & 5 task	Introduced in former D6.2**Error! Bookmark not defined.**	1. Agree with "Test Domain" upon Criteria; 2. Define grading scores; 3. Define guidelines for Network Application under test.
Design of certification agreement	WP6 task	Not defined yet	
Design of certification report	WP6 task	Not defined yet	
Design of end Certificate	WP6 task	Not defined yet	
Test Implementation	WP3, 4 & 5 Task	Ongoing, with advances in new test definitions and development on the test platform	1. Continue adding new test; 2. Do low-level definition of already agreed new and old test; 3. Integration and develop of required tools, emulators and supported mechanism, like NEF, traffic impairment, security testing descriptors, etc.

5.1 Status on the Certification Test Cases Implementation

Table 8 presents the status of certification test cases implementation, listing which test case have already been implemented by this deliverable's submission date.

Table 8 Status on the Certification Test Cases Implementation

Certification Definition ID	Test Case ID	Test Case	Development Status
5G Readiness Axis Test Cases			
11	def11.5G.1	Authentication with 5GS	Not Developed
11	def11.5G.2	Acquisition of UE location	Not Developed
11	def11.5G.3	Acquisition of UE handover event	Developed
11	def11.5G.4	Acquisition of UE RSSI information	Not Developed
11	def11.5G.5	Acquisition of UE path loss	Not Developed
11	def11.5G.6	Acquisition of serving cell information	Not Developed
11	def11.5G.7	Acquisition of QoS sustainability	Developed
Security & Privacy Axis Test Cases			
19	1	Network Application Package Integrity	Not Developed
19	2	VNFs should use a security-group offered by testbed	Developed
19	3	Openstack Port Security	Developed
19	4	SSL Protected APIs	Developed
19	5	Secure SSH Credentials	Developed
19	6	Protected/ Encrypted Interfaces	Not Developed
19	7	Open Ports	Developed
19	8	SSH Server Security	Developed
19	9	NEF Authentication	Developed
Performance & Scalability Axis Test Cases			
14	1	E2E throughput & latency performance, single UE	Not Developed
14	2	Management of multiple UEs, multiple User Plane (UP) streams	Not Developed
14	3	E2E throughput & latency performance, single UE	Not Developed
14	4	Management of multiple UEs (scale out)	Not Developed

14	5	Management of multiple UEs (RAN monitoring)	Not Developed
14	6	Management of multiple UEs (BW)	Not Developed
14	7	NEF signaling performance (e.g. handover notices)	Not Developed
14	8	Network Application - web performance (static page)	Not Developed
14	9	Network Application - API performance - response time	Not Developed
14	10	Network Application - API performance - requests per second	Not Developed
14	11	Network Application - API performance - maximum number of connections	Not Developed
14	12	Network Application - IP latency	Not Developed
14	13	Network Application - IP throughput	Not Developed
14	14	Network Application - IP RTT	Not Developed
14	15	Network Application - IP Traceroute	Not Developed
Availability & Continuity Axis Test Cases			
12	def12.AvailCont.1	Network Application continues its proper functioning after restricted bandwidth scenario	Not Developed
12	def12.AvailCont.2	Network Application continues its proper functioning after an introduced delay scenario	Not Developed
12	def12.AvailCont.3	Network Application continues its proper functioning after an introduced packet loss scenario	Not Developed
12	def12.AvailCont.4	Network Application continues its proper functioning after an introduced packet corruption scenario	Not Developed
12	def12.AvailCont.5	Network Application continues its proper functioning after an introduced total disruption of communication scenario	Not Developed

5.2 5GASP Certification Process - Next Steps

Given the actual status of the definition and implementation of the Certification pipelines, the timeline from *Figure 2* had been added.

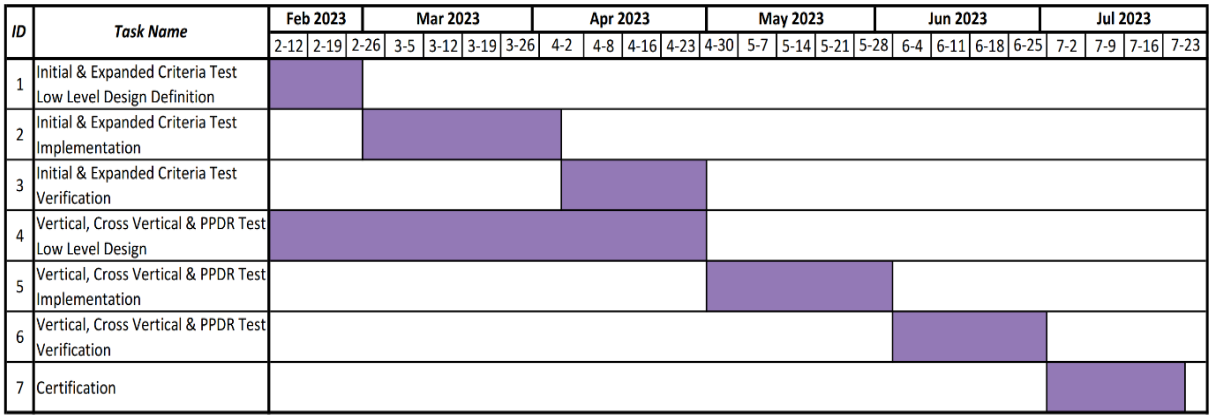


Figure 2 Status of the definition and implementation of the Certification pipelines

The automated test access for the applications will be performed via Network App MiniAPI (the detailed description is presented in *Appendix A*).

6 Network Application testing preparations

In this section the preparation of the test results for each Network Application will be centralized. The main focus here is to define a template for test result for the Network Application.

6.1 Network Application testing preliminary results - local tests

In this subsection, we present the preliminary results of the testing that has been already performed in all the testbeds of the project. Each testbed owner presents throughout this section the tests that have been locally instantiated and executed in its infrastructure, together with the initial obtained results.

6.1.1. Murcia site

In Murcia site different tests have been already developed and performed locally by OdinS team, using our infrastructure and manually executing the tests against the vOBU Network Application deployed. Both infrastructure and Network Application-specific tests have been successfully executed and validated with Network Application 1 vOBU. In the following, we showcase the results obtained with those tests. Although the infrastructure tests are performed over the vOBU components, they are not Network Application-specific because they are parametrized and the elements of the vOBU are passed as arguments. Thus, the tests evaluate the performance of the underlying infrastructure through the Network Application components.

- Deployment time

This test validates the deployment time of the Network Application, checking that the entities are deployed and ready to operate in less than 5 minutes. As it can be seen in *Figure 3*, the Network Application components are ready in less than 15 seconds.

Test Execution Log

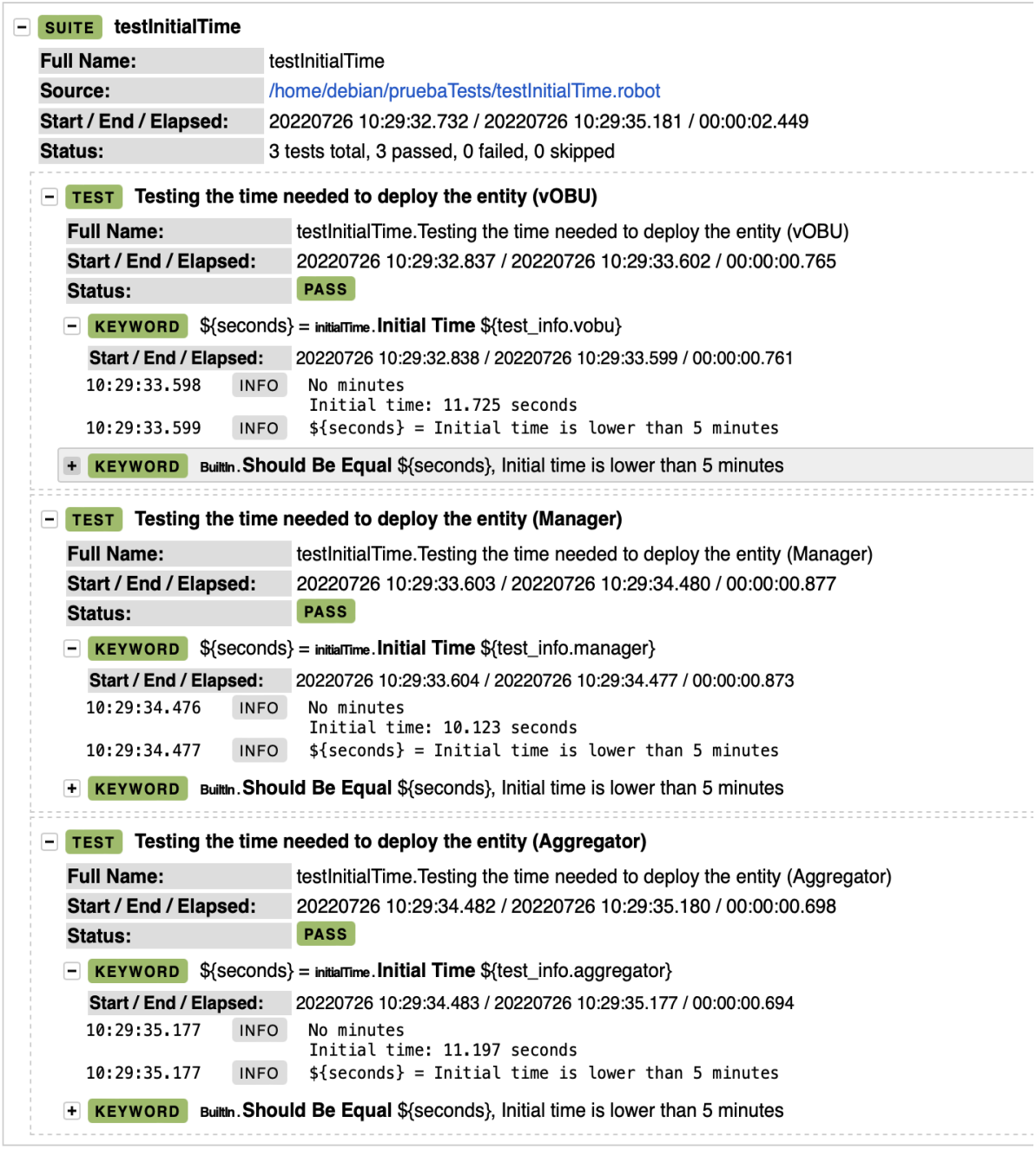


Figure 3 Deployment time test results

- Deployment check

The deployment check test validates that the VNFs have been successfully deployed and they have connectivity with each other. In *Figure 4* the results are shown.

Test Execution Log

SUITE **simpleDeployment**

Full Name: simpleDeployment
Source: /home/debian/pruebaTests/simpleDeployment.robot
Start / End / Elapsed: 20220726 10:59:03.543 / 20220726 10:59:06.508 / 00:00:02.965
Status: 7 tests total, 7 passed, 0 failed, 0 skipped

TEST **Testing the deployment of vOBU NetApp**
Full Name: simpleDeployment.Testing the deployment of vOBU NetApp
Start / End / Elapsed: 20220726 10:59:03.635 / 20220726 10:59:03.695 / 00:00:00.060
Status: PASS
KEYWORD ${value} = simpleDeployment . **Check Deployment** ${test_info.manager}, ${test_info.aggregator}, ${test_info.vobu}
KEYWORD BuiltIn . **Should Be Equal** ${value}, Deployment was succesful

TEST **Testing vOBU connectivity - Provider Network**
Full Name: simpleDeployment.Testing vOBU connectivity - Provider Network
Start / End / Elapsed: 20220726 10:59:03.695 / 20220726 10:59:04.238 / 00:00:00.543
Status: PASS
KEYWORD ${value} = simpleDeployment . **Check Connectivity Vobu** ${test_info.manager}, ${test_info.aggregator}, ${test_info.vobu}
KEYWORD BuiltIn . **Should Be Equal** ${value}, vOBU can reach the other entities

TEST **Testing vOBU connectivity - Internal Network**
Full Name: simpleDeployment.Testing vOBU connectivity - Internal Network
Start / End / Elapsed: 20220726 10:59:04.239 / 20220726 10:59:04.611 / 00:00:00.372
Status: PASS
KEYWORD ${value} = simpleDeployment . **Check Connectivity Vobu Internal**
KEYWORD BuiltIn . **Should Be Equal** ${value}, vOBU can reach the other entities

TEST **Testing Aggregator connectivity - Provider Network**
Full Name: simpleDeployment.Testing Aggregator connectivity - Provider Network
Start / End / Elapsed: 20220726 10:59:04.612 / 20220726 10:59:05.116 / 00:00:00.504
Status: PASS
KEYWORD ${value} = simpleDeployment . **Check Connectivity Aggregator** ${test_info.manager}, ${test_info.aggregator}, ${test_info.vobu}
KEYWORD BuiltIn . **Should Be Equal** ${value}, Aggregator can reach the other entities

TEST **Testing Aggregator connectivity - Internal Network**
Full Name: simpleDeployment.Testing Aggregator connectivity - Internal Network
Start / End / Elapsed: 20220726 10:59:05.117 / 20220726 10:59:05.554 / 00:00:00.437
Status: PASS
KEYWORD ${value} = simpleDeployment . **Check Connectivity Aggregator Internal**
KEYWORD BuiltIn . **Should Be Equal** ${value}, Aggregator can reach the other entities

TEST **Testing Manager connectivity - Provider Network**
Full Name: simpleDeployment.Testing Manager connectivity - Provider Network
Start / End / Elapsed: 20220726 10:59:05.555 / 20220726 10:59:06.058 / 00:00:00.503
Status: PASS
KEYWORD ${value} = simpleDeployment . **Check Connectivity Manager** ${test_info.manager}, ${test_info.aggregator}, ${test_info.vobu}
KEYWORD BuiltIn . **Should Be Equal** ${value}, Manager can reach the other entities

TEST **Testing Manager connectivity - Internal Network**
Full Name: simpleDeployment.Testing Manager connectivity - Internal Network
Start / End / Elapsed: 20220726 10:59:06.059 / 20220726 10:59:06.506 / 00:00:00.447
Status: PASS
KEYWORD ${value} = simpleDeployment . **Check Connectivity Manager Internal**
KEYWORD BuiltIn . **Should Be Equal** ${value}, Manager can reach the other entities

Figure 4 Deployment check test results

- Packet Loss Ratio

This test evaluates the Packet Loss Ratio (PLR) among the different components of the Network Application. It must be lower than 1%. *Figure 5* shows the results of the execution with the vOBU.

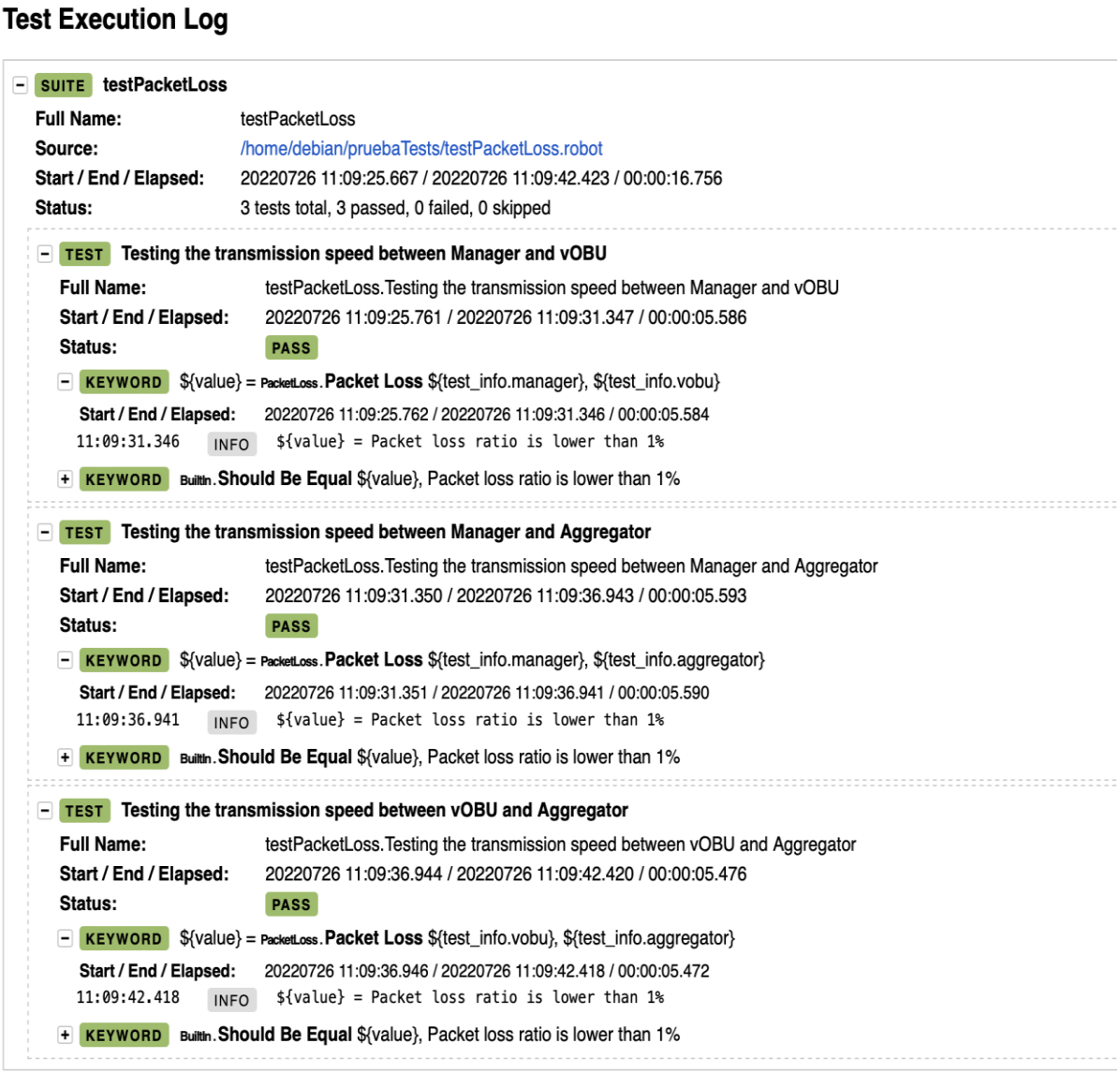


Figure 5 Packet Loss Ratio test results

- Latency

This test evaluates the latency among the different entities of the Network Application, it must be less than 500 ms. *Figure 6* and *Figure 7* show the results.

Test Execution Log

SUITE **pingTest**

Full Name:	pingTest
Source:	/home/debian/pruebaTests/pingTest.robot
Start / End / Elapsed:	20220726 11:12:21.553 / 20220726 11:12:34.797 / 00:00:13.244
Status:	3 tests total, 3 passed, 0 failed, 0 skipped

TEST **Testing the ping time between our entity and vOBU**

Full Name:	pingTest.Testing the ping time between our entity and vOBU
Start / End / Elapsed:	20220726 11:12:21.642 / 20220726 11:12:26.052 / 00:00:04.410
Status:	PASS

KEYWORD ${milliseconds} = pingTest . **Ping Test** ${test_info.vobu}

Start / End / Elapsed: 20220726 11:12:21.642 / 20220726 11:12:26.050 / 00:00:04.408

```
11:12:26.049 INFO PING 10.205.57.71 (10.205.57.71) 56(84) bytes of data.
64 bytes from 10.205.57.71: icmp_seq=1 ttl=64 time=0.034 ms
64 bytes from 10.205.57.71: icmp_seq=2 ttl=64 time=0.056 ms
64 bytes from 10.205.57.71: icmp_seq=3 ttl=64 time=0.051 ms
64 bytes from 10.205.57.71: icmp_seq=4 ttl=64 time=0.052 ms
64 bytes from 10.205.57.71: icmp_seq=5 ttl=64 time=0.052 ms

--- 10.205.57.71 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 108ms
rtt min/avg/max/mdev = 0.034/0.049/0.056/0.007 ms

AVG: 0.049
11:12:26.050 INFO ${milliseconds} = Less than 500 milliseconds
```

KEYWORD BuiltIn . **Should Be Equal** ${milliseconds}, Less than 500 milliseconds

TEST **Testing the ping time between our entity and Manager**

Full Name:	pingTest.Testing the ping time between our entity and Manager
Start / End / Elapsed:	20220726 11:12:26.053 / 20220726 11:12:30.409 / 00:00:04.356
Status:	PASS

KEYWORD ${milliseconds} = pingTest . **Ping Test** ${test_info.manager}

Start / End / Elapsed: 20220726 11:12:26.054 / 20220726 11:12:30.407 / 00:00:04.353

```
11:12:30.406 INFO PING 10.205.57.91 (10.205.57.91) 56(84) bytes of data.
64 bytes from 10.205.57.91: icmp_seq=1 ttl=64 time=0.042 ms
64 bytes from 10.205.57.91: icmp_seq=2 ttl=64 time=0.062 ms
64 bytes from 10.205.57.91: icmp_seq=3 ttl=64 time=0.056 ms
64 bytes from 10.205.57.91: icmp_seq=4 ttl=64 time=0.058 ms
64 bytes from 10.205.57.91: icmp_seq=5 ttl=64 time=0.059 ms

--- 10.205.57.91 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 85ms
rtt min/avg/max/mdev = 0.042/0.055/0.062/0.009 ms

AVG: 0.055
11:12:30.407 INFO ${milliseconds} = Less than 500 milliseconds
```

Figure 6 Latency test results 1

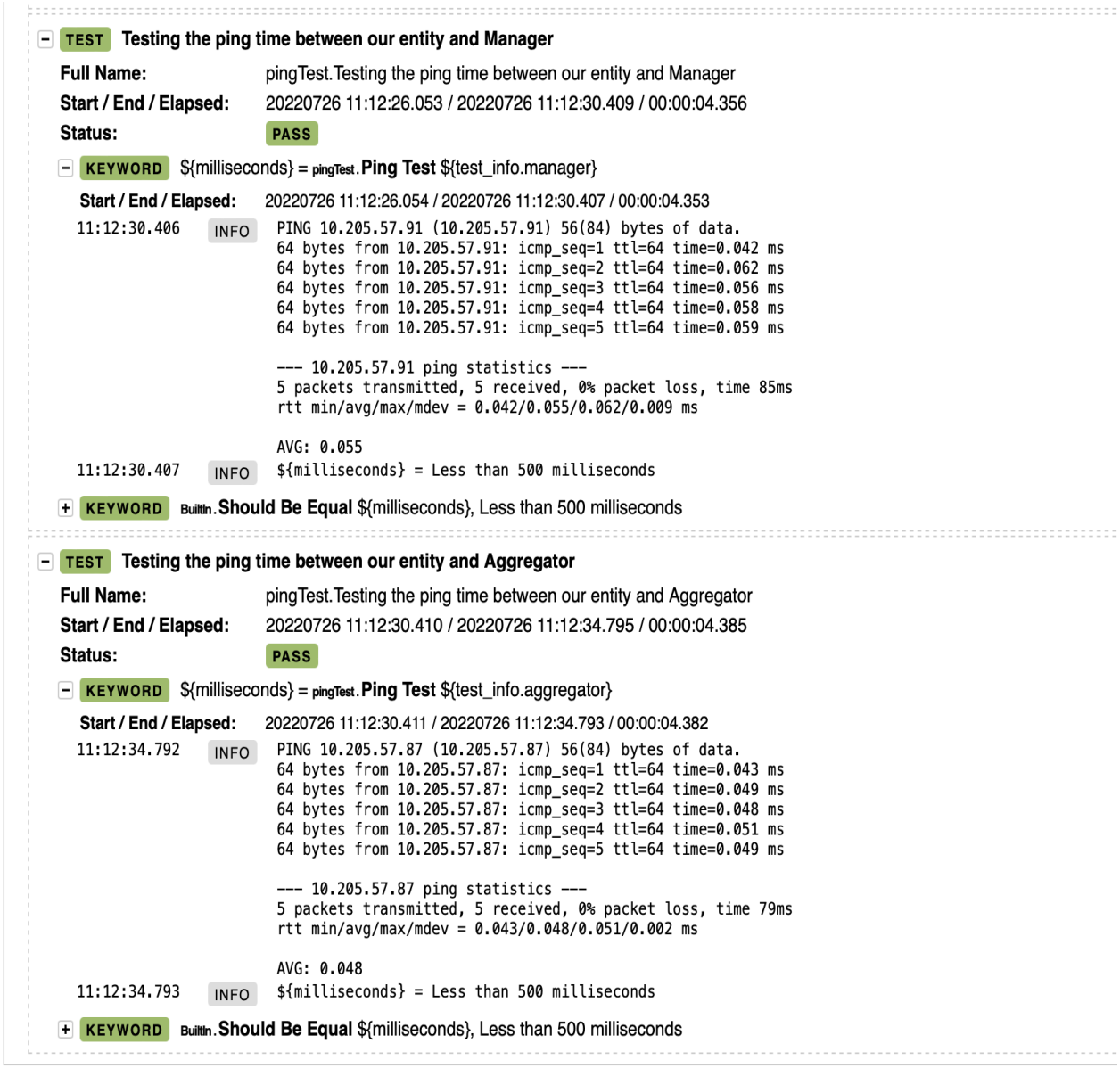


Figure 7 Latency test results 2

- vOBU API Request

This is a vOBU Network Application specific test, which evaluates if the APIs of the different components of the vOBU are ready to operate. To do so, it sends multiple requests to the vOBU endpoints to validate their functioning. In *Figure 8*, the results of the execution can be seen.

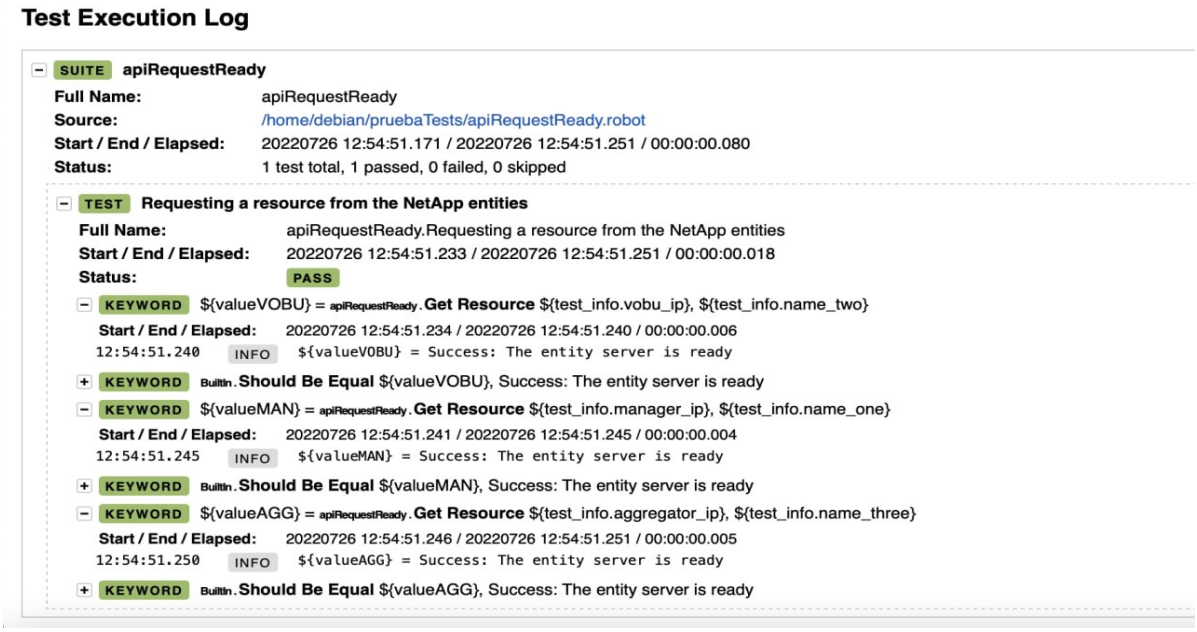


Figure 8 vOBU API Request test results

- Database ready

This is a vOBU Network Application specific test, which evaluates if the databases that are embedded in the components of the vOBU Network Applications are ready to receive requests. To do so, it sends several requests to the vOBU service acting as an external client requesting special values that have been already stored in the databases and measuring the access time, which will vary depending on where is each value. In this case, one of these special values has been purposely removed from the database located in the aggregator entity to check if the validation fails. In *Figure 9* it can be seen that the test has failed.

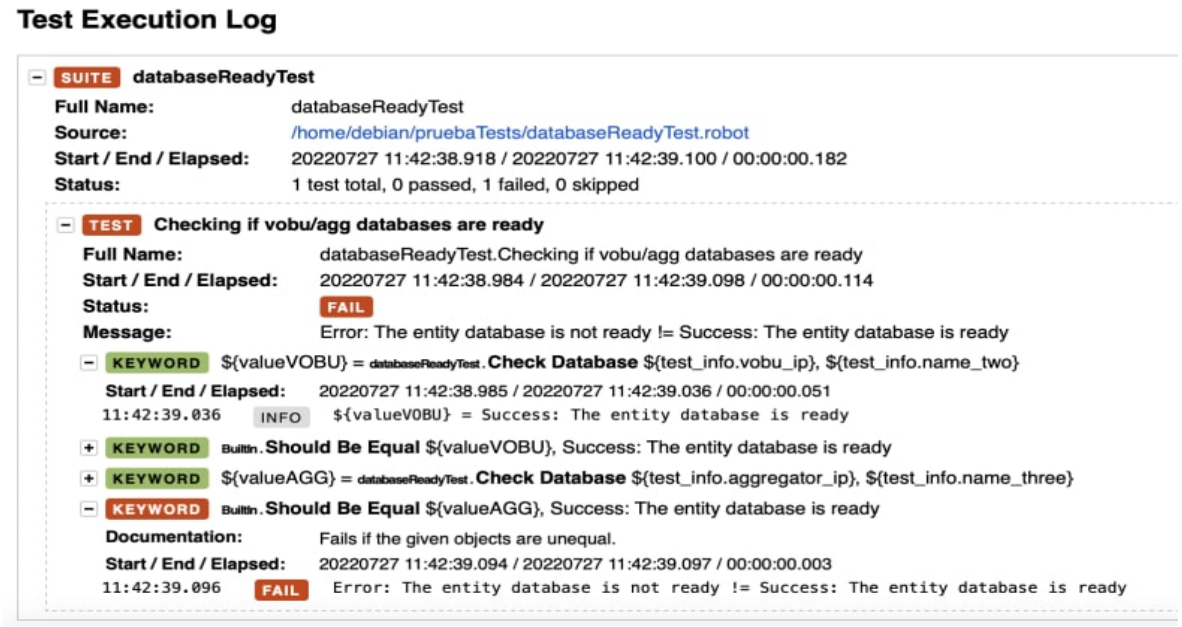


Figure 9 Database ready failed test results

6.1.2. Aveiro site

Since ITAv is not the owner of any of the 5GASP Network Applications, it tested OdinS' vOBU Network Application using some of the certification-defined test cases. This testing process differed from the one showcased in Section 6.1.1 since it was performed automatically through 5GASP's CI/CD Service.

The results gathered from the validation process performed in ITAv can be seen as preliminary certification results and thus are showcased in Section 7.

6.1.3. Bristol site

The Bristol site has implemented preliminary tests for Network Application 7 (Efficient MEC Handover). The tests are designed to verify the APIs published by the Network Application, aimed to be consumed by local monitoring frameworks and other Network Applications. The test results are shown in the following figures. The **GET API** request is verified using the test shown the *Figure 10,* which shows the API is up and running to serve the other Network Applications. The response code of the **POST request** is verified in the test shown in *Figure 11*. The output of the **POST response** is verified using the test cases in the *Figure 12* and *Figure 13*. *Figure 14* shows the failed result in case the API is not reachable and the service is not running.

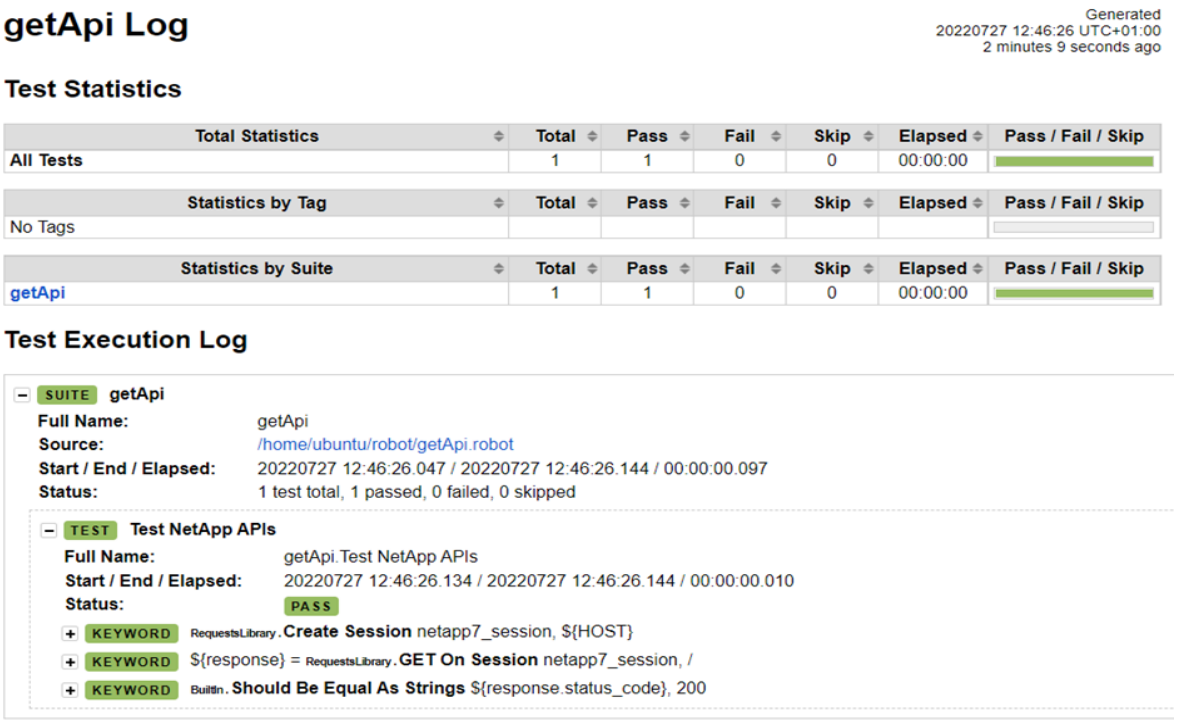


Figure 10 GET API Test Result

Test Execution Log

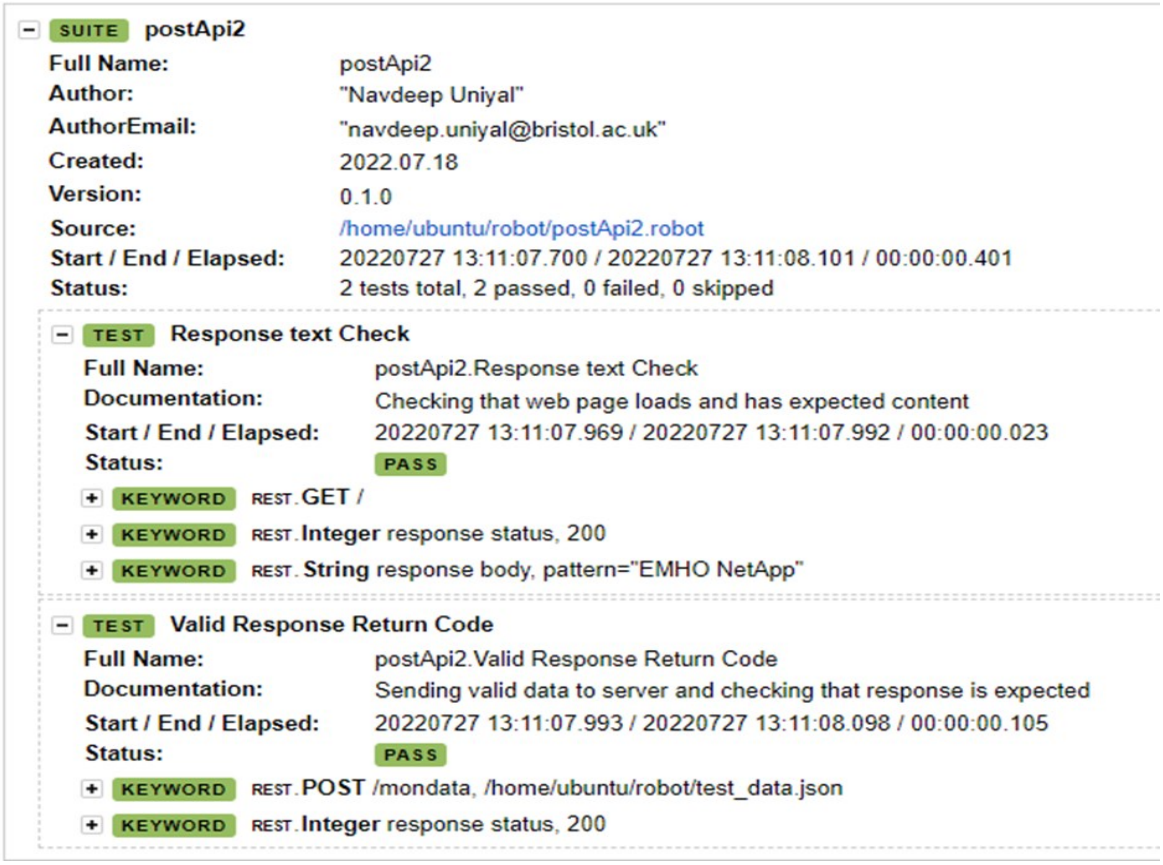


Figure 11 POST API Response code check

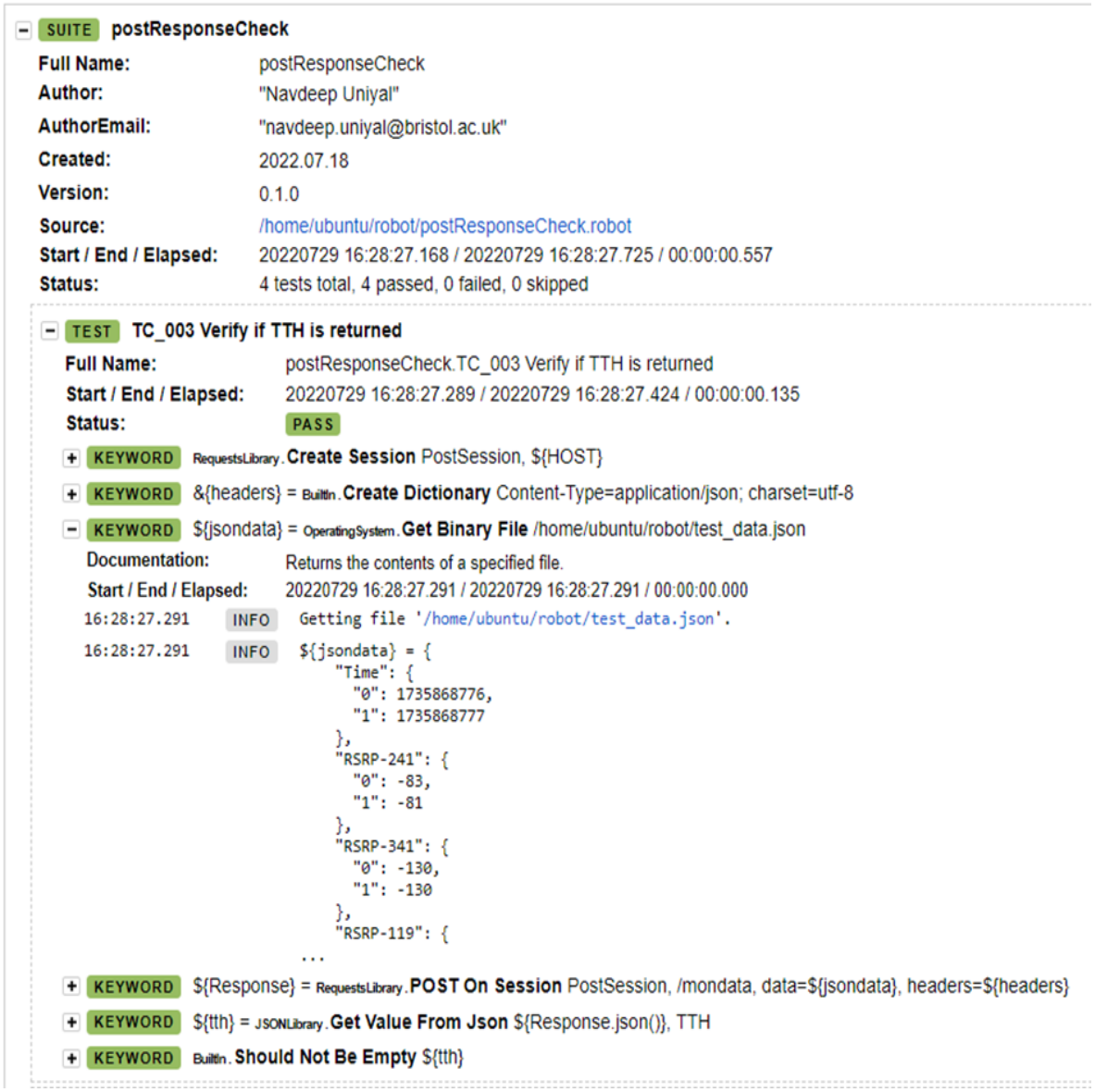


Figure 12 POST Request output key verification-1

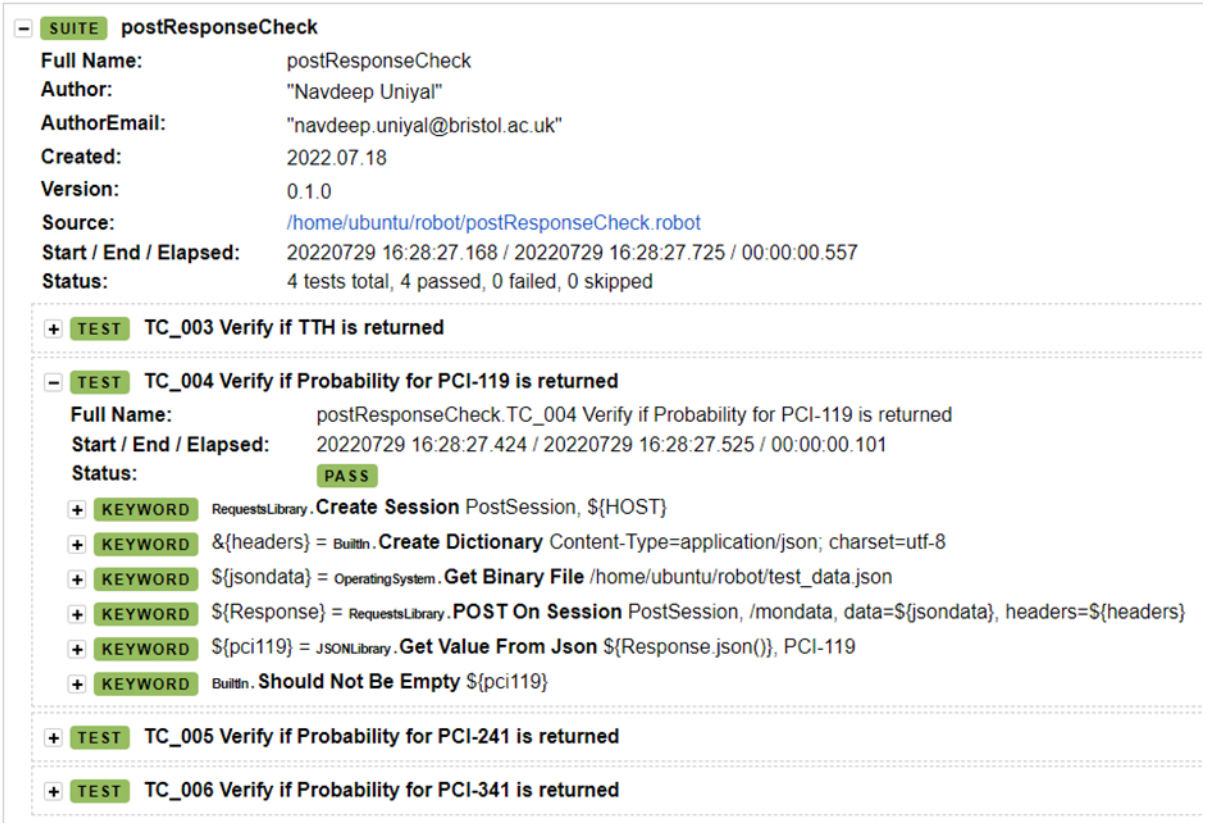


Figure 13 POST Request output key verification-2

Test Execution Log

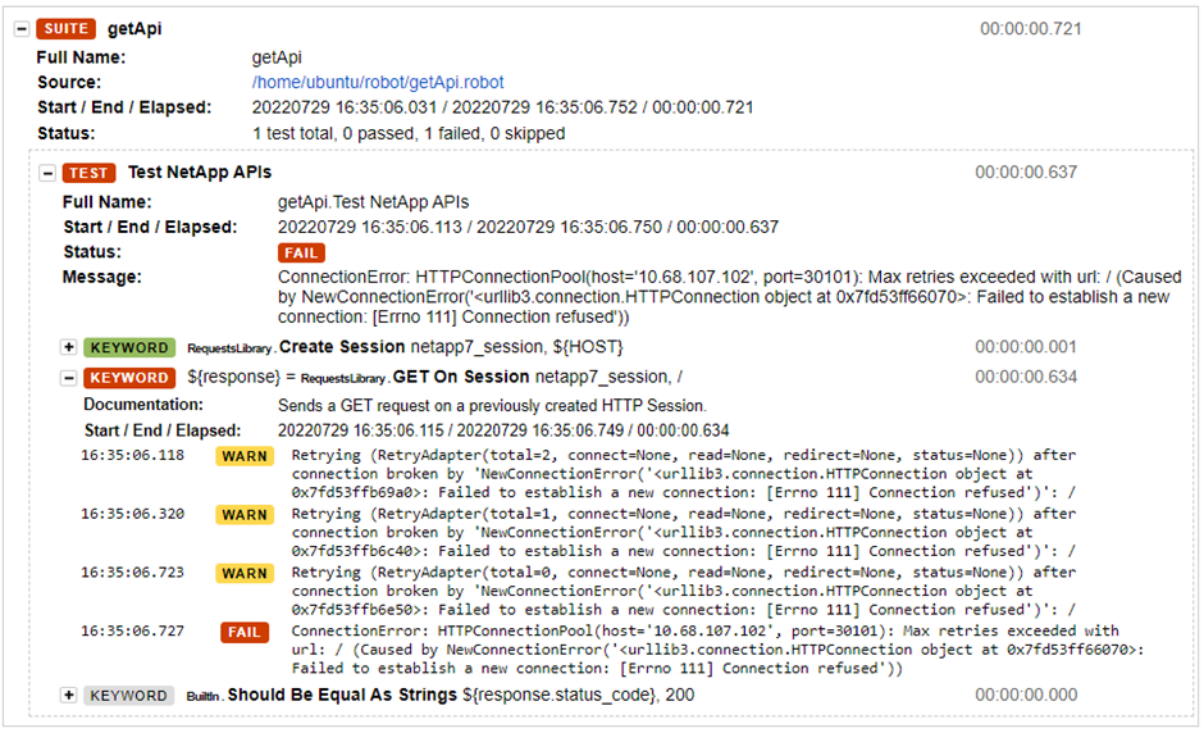


Figure 14 Failed test- GET API failed (Service not running)

6.1.4. Patras site

Patras site prioritized the development and testing of its in-house Network Application, i.e. Network Application 11 or Fire Detection and Ground Assistance using Drones (FIDEGAD). Subsequently, the Network Application-specific tests were designed and developed focused on validating the proper functioning of Network Application components. The Network Application consists of three main components, i.e. a video stream client, an image recognition server and the visualization dashboard, respectively. Therefore, an initial test is designed to certify that the visualization dashboard is accessible through its dynamically appointed IP address. Hereafter, a functional test is introduced to confirm the expected outcome of the image recognition service. To that end, a predetermined video stream is provided to the recognition service and is tested against specific frames, where the first is presumed to trigger the fire detection mechanism and the latter should not, accordingly. Both test cases' results are illustrated in *Figure 15.*

Tests Performed

Test ID	Test Name	Start	End	Test Status	Test Description	Test Log	Test Report
1	dashboard_readiness_test	2023-01-20 15:12:52	2023-01-20 15:12:52	Passed	Test the accessibility of the vizualization dashboard	Test Log	Test Report
2	recognition_service_test	2023-01-20 15:12:53	2023-01-20 15:12:55	Passed	Confirm the proper functioning of the fire recognition service	Test Log	Test Report

Figure 15 Results of the tests executed on FIDEGAD Network Application at Patras site

6.1.5. Bucharest site

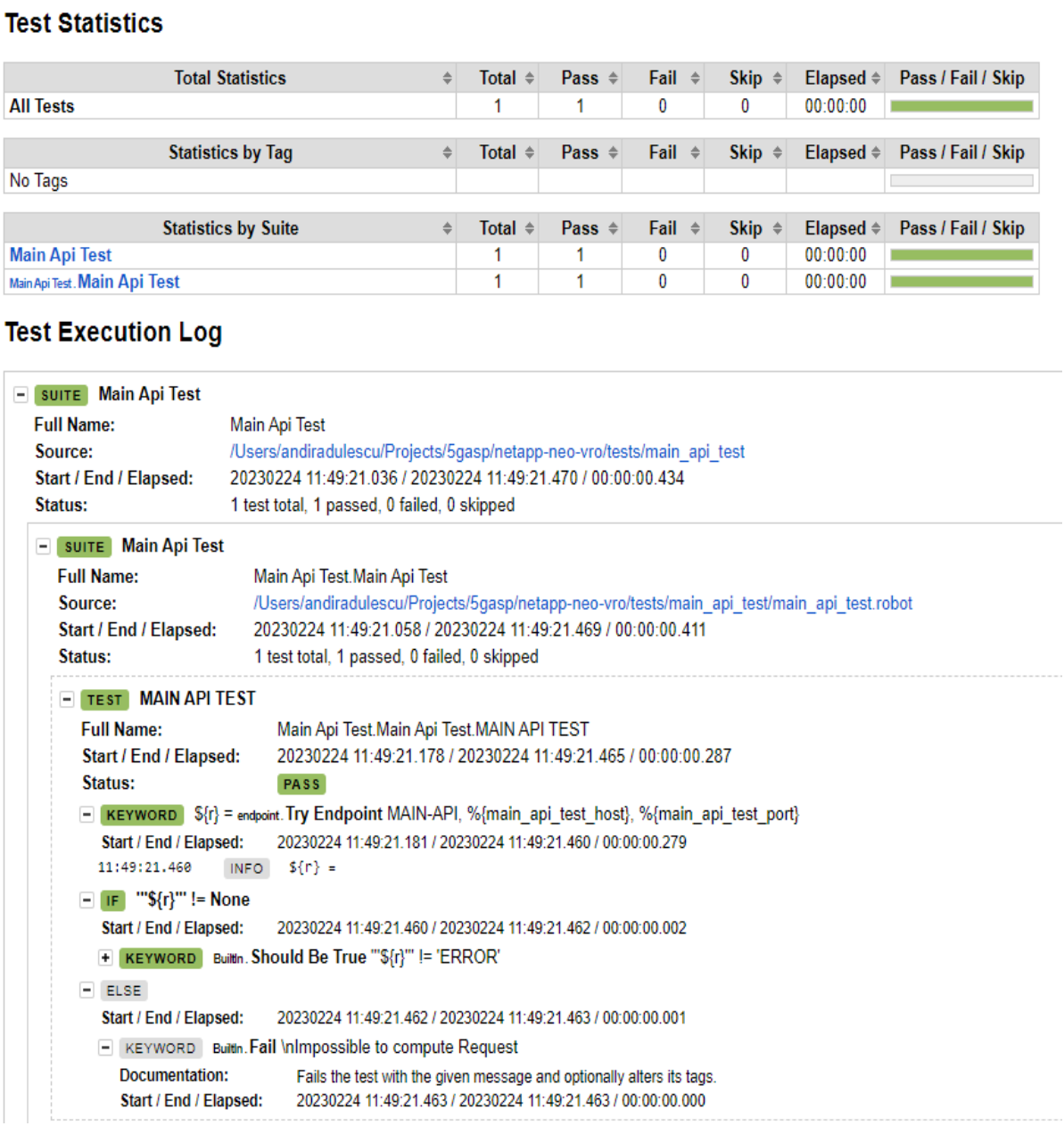
Orange Romania testbed has implemented the tests for Network Application 10 (Vehicle Route Optimizer). This Network Application is a Cloud-native Network Function (CNF) made up of 4 components (also called services) which are pods in a Kubernetes cluster infrastructure. After the deployment phase, using 5GASP portal and testbed's Open Source MANO (OSM), the 4 pods are ready and the testing phase could proceed.

These tests are focused on the validation of the proper functioning of the Network Application services, which consists of four services:

User API ("main-api");

- Driver API ("neo-transport-api");
- Routing Engine ("neo-routing-engine");
- Open Source Routing Machine (OSRM) ("osrm").

An initial developer defined test suite, for each service, verifies that the APIs are correctly running by making specific HTTP requests to the APIs and interpreting the method's results. Those results are illustrated in the figures below. The Main API test results in *Figure 16* show that the user facing API is able to take bus orders.



Test Statistics

Total Statistics	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
All Tests	1	1	0	0	00:00:00	

Statistics by Tag	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
No Tags						

Statistics by Suite	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
Main Api Test	1	1	0	0	00:00:00	
Main Api Test.Main Api Test	1	1	0	0	00:00:00	

Test Execution Log

SUITE Main Api Test
Full Name: Main Api Test
Source: /Users/andiradulescu/Projects/5gasp/netapp-neo-vro/tests/main_api_test
Start / End / Elapsed: 20230224 11:49:21.036 / 20230224 11:49:21.470 / 00:00:00.434
Status: 1 test total, 1 passed, 0 failed, 0 skipped

SUITE Main Api Test
Full Name: Main Api Test.Main Api Test
Source: /Users/andiradulescu/Projects/5gasp/netapp-neo-vro/tests/main_api_test/main_api_test.robot
Start / End / Elapsed: 20230224 11:49:21.058 / 20230224 11:49:21.469 / 00:00:00.411
Status: 1 test total, 1 passed, 0 failed, 0 skipped

TEST MAIN API TEST
Full Name: Main Api Test.Main Api Test.MAIN API TEST
Start / End / Elapsed: 20230224 11:49:21.178 / 20230224 11:49:21.465 / 00:00:00.287
Status: PASS

KEYWORD ${r} = endpoint. Try Endpoint MAIN-API, %{main_api_test_host}, %{main_api_test_port}
Start / End / Elapsed: 20230224 11:49:21.181 / 20230224 11:49:21.460 / 00:00:00.279
11:49:21.460 INFO ${r} =

IF '"${r}" != None
Start / End / Elapsed: 20230224 11:49:21.460 / 20230224 11:49:21.462 / 00:00:00.002
KEYWORD BuiltIn. Should Be True '"${r}" != 'ERROR'

ELSE
Start / End / Elapsed: 20230224 11:49:21.462 / 20230224 11:49:21.463 / 00:00:00.001
KEYWORD BuiltIn. Fail \nImpossible to compute Request
Documentation: Fails the test with the given message and optionally alters its tags.
Start / End / Elapsed: 20230224 11:49:21.463 / 20230224 11:49:21.463 / 00:00:00.000

Figure 16 Main API test result for Network Application 10

The Neo Transport API test results in *Figure 17* verify that the driver facing API is able to process orders.

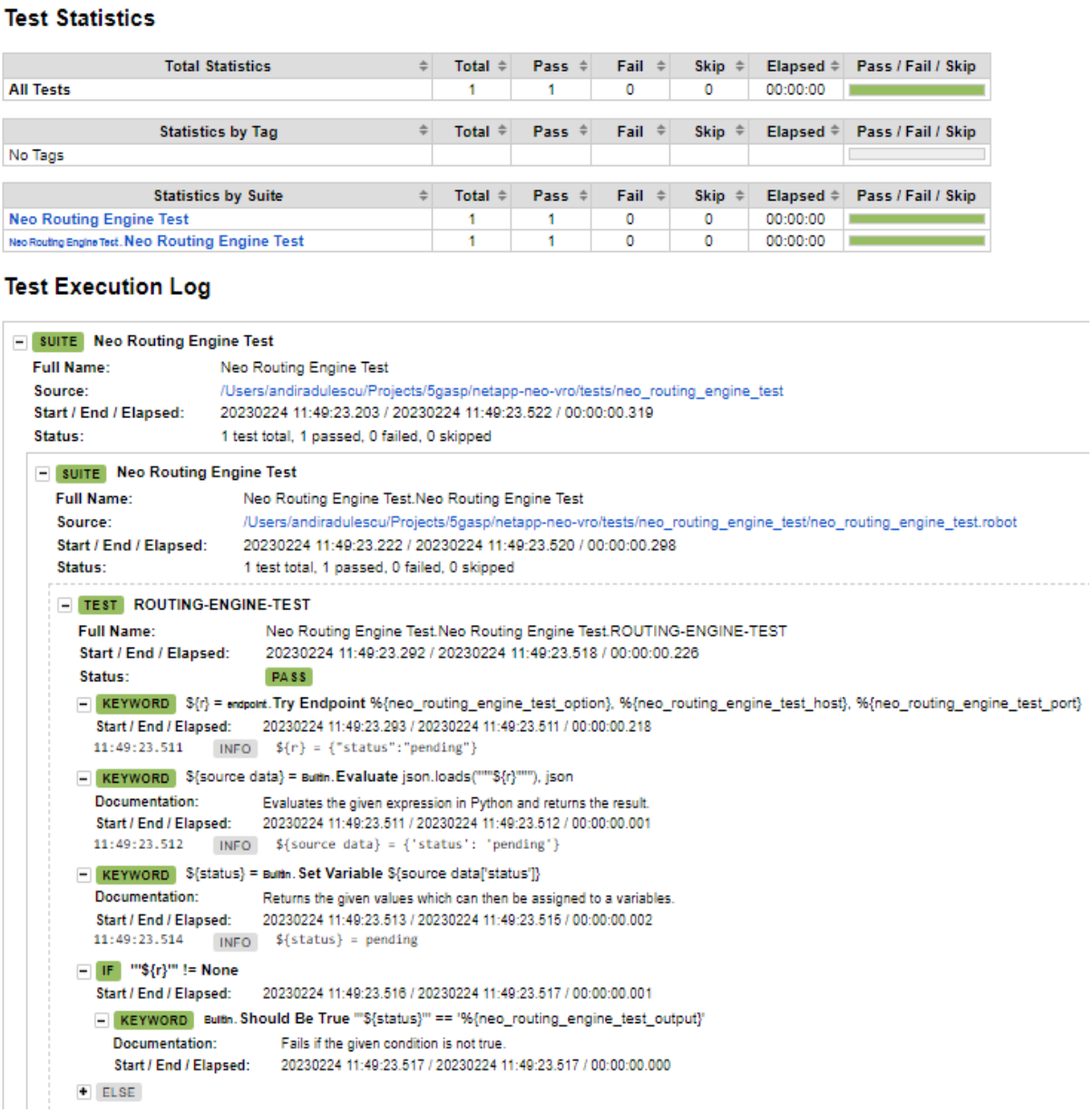


Figure 17 Driver API test result for Network Application 10

The Neo Routing Engine has two test suites, one of which is shown in *Figure 18*, which verifies that the engine is able to take an order and start processing it.

Test Statistics

Total Statistics	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
All Tests	1	1	0	0	00:00:00	

Statistics by Tag	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
No Tags						

Statistics by Suite	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
Neo Routing Engine Test	1	1	0	0	00:00:00	
Neo Routing Engine Test.Neo Routing Engine Test	1	1	0	0	00:00:00	

Test Execution Log

SUITE Neo Routing Engine Test
Full Name: Neo Routing Engine Test
Source: /Users/andiradulescu/Projects/5gasp/netapp-neo-vro/tests/neo_routing_engine_test
Start / End / Elapsed: 20230224 11:49:23.203 / 20230224 11:49:23.522 / 00:00:00.319
Status: 1 test total, 1 passed, 0 failed, 0 skipped

SUITE Neo Routing Engine Test
Full Name: Neo Routing Engine Test.Neo Routing Engine Test
Source: /Users/andiradulescu/Projects/5gasp/netapp-neo-vro/tests/neo_routing_engine_test/neo_routing_engine_test.robot
Start / End / Elapsed: 20230224 11:49:23.222 / 20230224 11:49:23.520 / 00:00:00.298
Status: 1 test total, 1 passed, 0 failed, 0 skipped

TEST ROUTING-ENGINE-TEST
Full Name: Neo Routing Engine Test.Neo Routing Engine Test.ROUTING-ENGINE-TEST
Start / End / Elapsed: 20230224 11:49:23.292 / 20230224 11:49:23.518 / 00:00:00.226
Status: PASS

KEYWORD ${r} = endpoint. **Try Endpoint** %{neo_routing_engine_test_option}, %{neo_routing_engine_test_host}, %{neo_routing_engine_test_port}
Start / End / Elapsed: 20230224 11:49:23.293 / 20230224 11:49:23.511 / 00:00:00.218
11:49:23.511 INFO ${r} = {"status":"pending"}

KEYWORD ${source data} = BuiltIn. **Evaluate** json.loads("""${r}"""), json
Documentation: Evaluates the given expression in Python and returns the result.
Start / End / Elapsed: 20230224 11:49:23.511 / 20230224 11:49:23.512 / 00:00:00.001
11:49:23.512 INFO ${source data} = {'status': 'pending'}

KEYWORD ${status} = BuiltIn. **Set Variable** ${source data['status']}
Documentation: Returns the given values which can then be assigned to a variables.
Start / End / Elapsed: 20230224 11:49:23.513 / 20230224 11:49:23.515 / 00:00:00.002
11:49:23.514 INFO ${status} = pending

IF '"${r}"' != None
Start / End / Elapsed: 20230224 11:49:23.516 / 20230224 11:49:23.517 / 00:00:00.001

KEYWORD BuiltIn. **Should Be True** '"${status}"' == '%{neo_routing_engine_test_output}'
Documentation: Fails if the given condition is not true.
Start / End / Elapsed: 20230224 11:49:23.517 / 20230224 11:49:23.517 / 00:00:00.000

ELSE

Figure 18 Routing engine test result for Network Application 10

The OSRM test suite has two tests, one of which is shown in *Figure 19*, that verify that it is able to calculate distance and time from two geographical points.

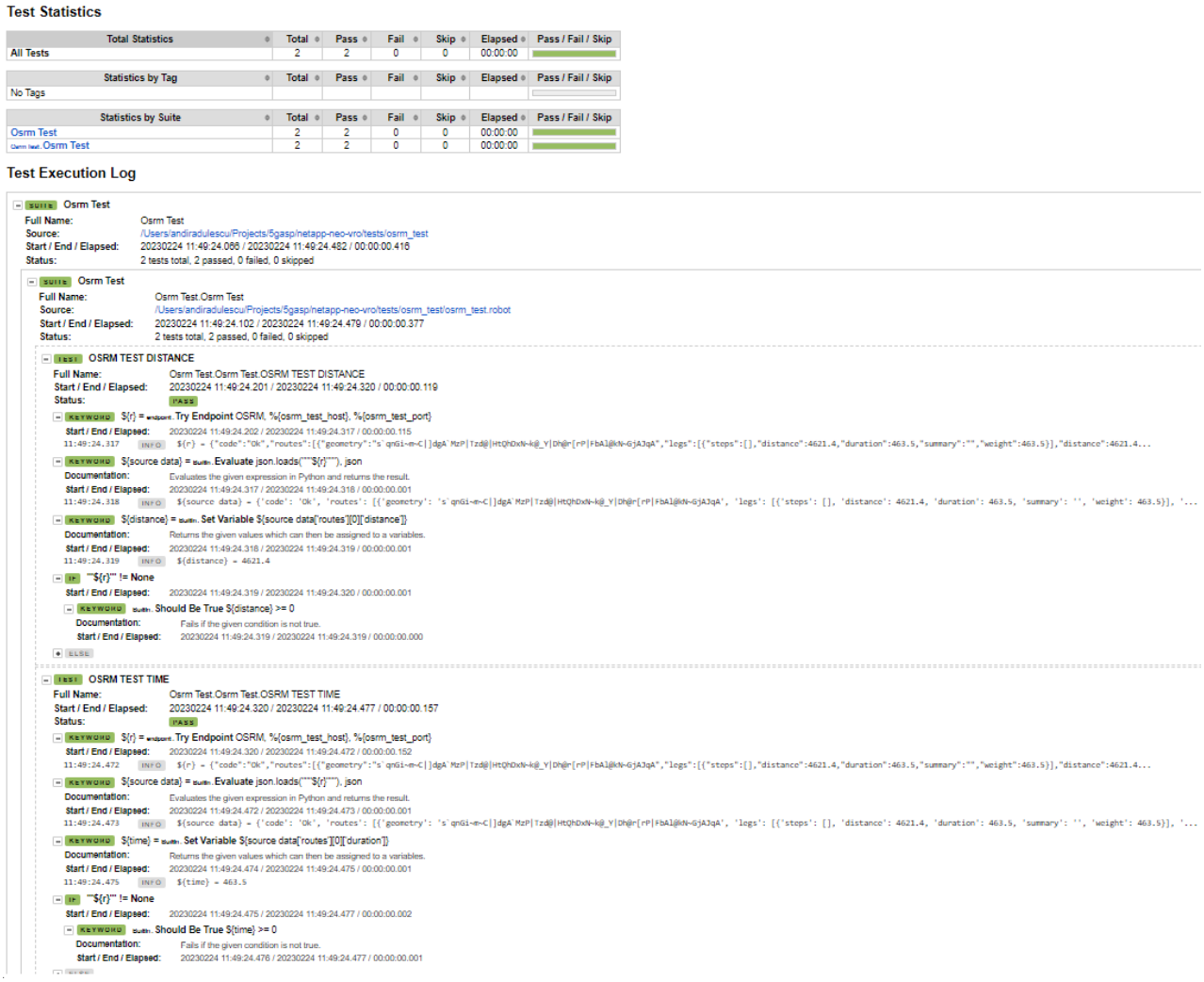


Figure 19 OSRM test result for Network Application 10

The CI/CD Manager orchestrated all tests and their results were collected and made available via the Test Results Visualization Dashboard, as shown in *Figure 20*.

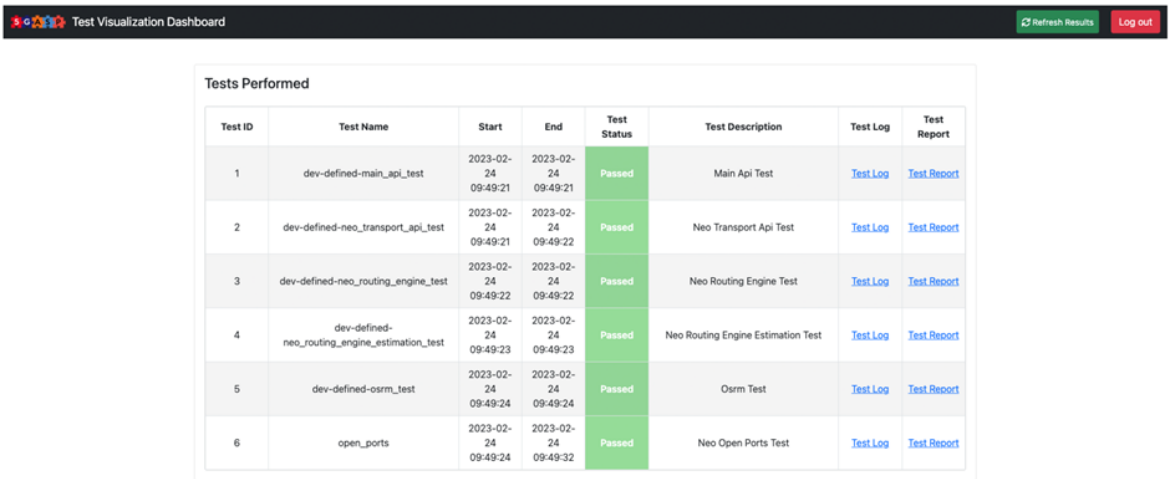


Figure 20 Results of the tests executed on Vehicle Route Optimizer Network Application in ORO Testbed

6.1.6. Ljubljana Site

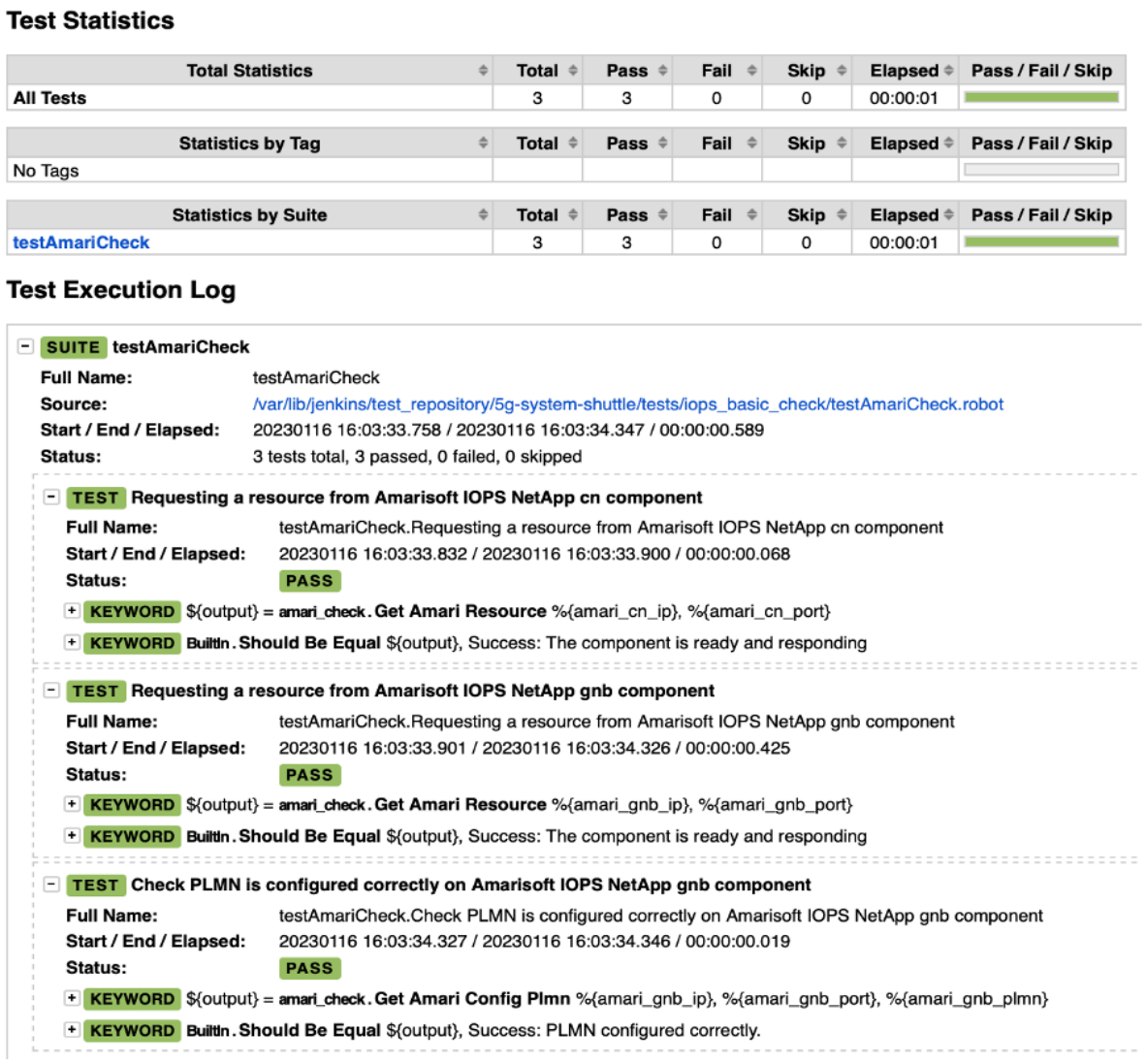
Ljubljana testbed currently provides some initial test cases regarding the testbed's 5G infrastructure services and deployment, which also serve as a basis for Network Application test cases and additional development regarding Public Protection and Disaster Relief (PPDR) vertical test cases. First test cases for IOPS Network Application were already developed and were executed to provide some initial test results.

Network Application's 5G services and deployment (readiness) tests are currently manually triggered through Jenkins (*Figure 21*). Test cases shown in the following example report:

5G Core NS operation by checking if the API is being available and responding;

5G Next Generation Node B (gNB) NS operation by checking if the API is being available and responding;

5GS is provisioned with the correct Public Land Mobile Network (PLMN).



Test Statistics

Total Statistics	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
All Tests	3	3	0	0	00:00:01	

Statistics by Tag	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
No Tags						

Statistics by Suite	Total	Pass	Fail	Skip	Elapsed	Pass / Fail / Skip
testAmariCheck	3	3	0	0	00:00:01	

Test Execution Log

SUITE testAmariCheck
Full Name: testAmariCheck
Source: /var/lib/jenkins/test_repository/5g-system-shuttle/tests/iops_basic_check/testAmariCheck.robot
Start / End / Elapsed: 20230116 16:03:33.758 / 20230116 16:03:34.347 / 00:00:00.589
Status: 3 tests total, 3 passed, 0 failed, 0 skipped

TEST Requesting a resource from Amarisoft IOPS NetApp cn component
Full Name: testAmariCheck.Requesting a resource from Amarisoft IOPS NetApp cn component
Start / End / Elapsed: 20230116 16:03:33.832 / 20230116 16:03:33.900 / 00:00:00.068
Status: PASS
KEYWORD ${output} = amari_check.Get Amari Resource %{amari_cn_ip}, %{amari_cn_port}
KEYWORD BuiltIn.Should Be Equal ${output}, Success: The component is ready and responding

TEST Requesting a resource from Amarisoft IOPS NetApp gnb component
Full Name: testAmariCheck.Requesting a resource from Amarisoft IOPS NetApp gnb component
Start / End / Elapsed: 20230116 16:03:33.901 / 20230116 16:03:34.326 / 00:00:00.425
Status: PASS
KEYWORD ${output} = amari_check.Get Amari Resource %{amari_gnb_ip}, %{amari_gnb_port}
KEYWORD BuiltIn.Should Be Equal ${output}, Success: The component is ready and responding

TEST Check PLMN is configured correctly on Amarisoft IOPS NetApp gnb component
Full Name: testAmariCheck.Check PLMN is configured correctly on Amarisoft IOPS NetApp gnb component
Start / End / Elapsed: 20230116 16:03:34.327 / 20230116 16:03:34.346 / 00:00:00.019
Status: PASS
KEYWORD ${output} = amari_check.Get Amari Config Plmn %{amari_gnb_ip}, %{amari_gnb_port}, %{amari_gnb_plmn}
KEYWORD BuiltIn.Should Be Equal ${output}, Success: PLMN configured correctly.

Figure 21 Network Application's 5G services and deployment test execution log

Additionally, UE-based tests for the IOPS Network Application were developed to provide testing the IP connectivity from 5G UE attached to the PPDR slice provided by the Network Application (*Figure 22* and *Figure 23*):

- IP connectivity from 5G UE to the 5G Core Network (CN) (i.e. local service) by triggering PING test to the internal IP address of the CN via Quality Monitoring System (qMON) agent on the 5G UE;
- IP connectivity from 5G UE to the Internet (i.e. public service) by triggering PING test to some internet IP address via qMON agent on the 5G UE.

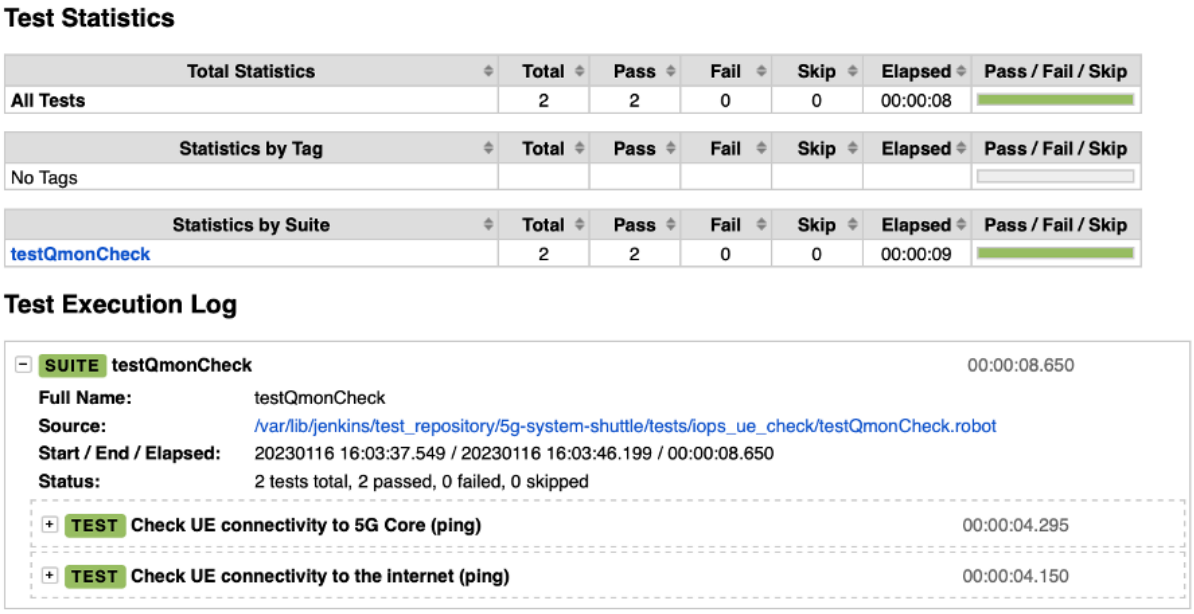


Figure 22 5G UE connectivity check test execution log overview

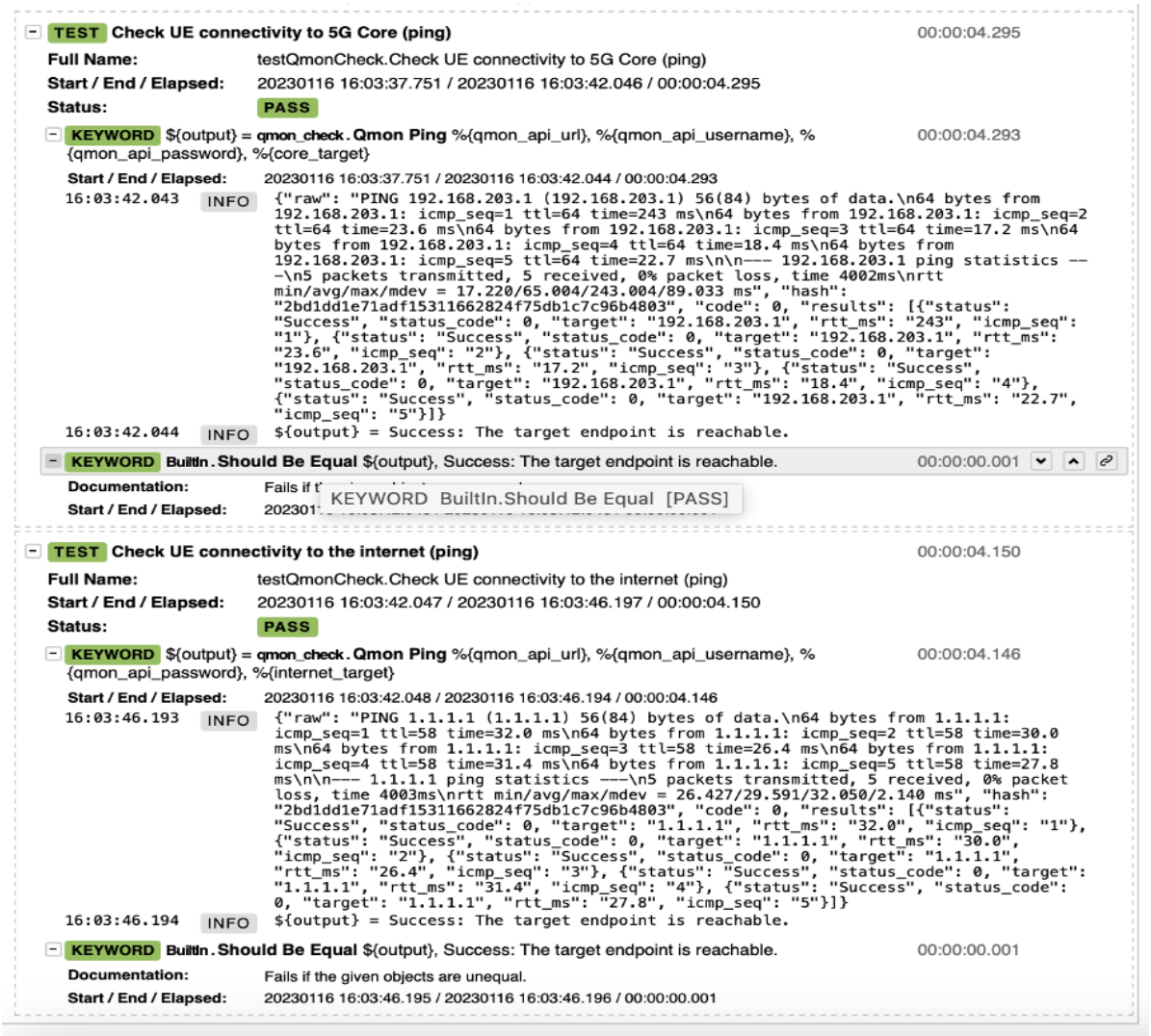


Figure 23 5G UE connectivity check test execution log details

6.2. Network Application Initial Test Plan

The Network Applications test plans can be differentiated into three different parts. From a top to down approach, the Network Application testing will comprehend from the general Network Application mandatory certification tests and its corresponding vertical-specific tests, to the particularly designed and developed tests from the Network Application developers and experimenters. Therefore, the Network Application test plan will cover the testing scopes from the more generic ones to the more Network Application-specific ones. By following this approach, the Network Application mandatory certification tests will be shared by the test plans of almost every Network Application. Regarding the vertical-specific tests, they will be shared by the Network Applications of each vertical, namely, automotive and PPDR. Finally, each Network Application will present its function and operational-specific set of tests that will conform the Network Application specific part of the test plan. In this subsection, we present the initial tests plans that have been designed for each Network Application.

6.2.1. NETWORK APPLICATION 1: VIRTUAL ON-BOARD UNIT PROVISIONING NETWORK APPLICATION (VOBU)

vOBU Network Application initial test plan is presented in *Table 9*:

Table 9 vOBU Network Application initial test plan

vOBU Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model	Pass / Fail	Developed
19	Follows 3GPP security definitions and recommendations	Pass / Fail	In design
Vertical specific tests: automotive vertical			
OBU 5G network register	This test validates that the OBU of the vehicle can effectively register in the 5G network	Pass / Fail	In design
OBU 5G network connectivity	This test validates that the OBU of the vehicle has 5G connectivity	Pass / Fail	In design
OBU 5G handover	This test validates that the OBU of the vehicle can effectively handover among gNBs in the 5G network	Pass / Fail	In design
Vehicular network monitoring	This test validates that the application server can consume monitoring and telemetry data from the vehicular network performance	Pass / Fail	In design
Application service continuity	This test validates that the application running in the vehicle does not interrupt its service after a handover	Pass / Fail	In design
System initiation	Verify the system initiation - the modules are up and reporting as running	Pass / Fail	In design

Cooperative Intelligent Transport Systems (C-ITS) uplink communication	A C-ITS message originated from the UE is received by other nodes	Pass / Fail	In design
C-ITS downlink communication	A C-ITS message originated from an external server is received by other nodes	Pass / Fail	In design
C-ITS congestion	Under high traffic load, a C-ITS message originated from the UE is received by other nodes	Pass / Fail	In design
C-ITS coverage	A C-ITS message originated from the UE out of the coverage zone of the vRSU is not received by other nodes	Pass / Fail	In design
C-ITS edge communication	A C-ITS message originated from a Network Application deployed on the edge is received by other nodes	Pass / Fail	In design
Network Application specific tests			
Simple HTTP request	Simple HTTP request to validate the functioning of the service	HTTP 200 OK	Developed
HTTP Burst request	HTTP burst request to validate the functioning of the service	HTTP 200 OK for all the burst	In design
vOBU request	Simulated request from an OBU asking for a vOBU	vOBU instantiation and connectivity OK with the OBU	In design
Data request and cached in Data Aggregator	Data request to the OBU from a consumer application asking for data that is present in the Data Aggregator so the request do not have to go through the vOBU	Data retrieved with the lowest latency thanks to the Data Aggregator	Developed
Data request and cached in vOBU	Data request to the OBU from a consumer application asking for data that is present in the vOBU (not in the Data	Data retrieved with more latency than in the previous case, but without	Developed

	Aggregator) so the request do not have to reach the OBU	reaching the OBU and not consuming radio resources	
vOBU release	Simulated release request from an OBU asking for the release of the used vOBU	vOBU release	In design

6.2.2 NETWORK APPLICATION 2: VIRTUAL ROADSIDE UNIT PROVISIONING NETWORK APPLICATION (VRSU)

vRSU Network Application initial test plan is presented in *Table 10*:

Table 10 vRSU Network Application initial test plan

vRSU Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model	Pass/Fail	Developed
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In design
Vertical specific tests: cross vertical			
E2E Packet Data Rate	Verify E2E Packet Data Rate of both Uplink and Downlink from the view of Network Application	1. Uplink >100 kbps for a single UE - Depending 2. Downlink >100 kbps for a single UE – Depending	In design
E2E Packet Latency edge Network Application	Verify E2E Packet Latency per path from the view of Network Application	<10 ms for a single UE	In design
E2E Packet Loss	Verify per communication path E2E Packet Loss from the view of Network Application	<0.025 %	In design

Network Application specific tests			
Cooperative Services	Test the Cooperative Awareness Messages (CAM) reception by sending a payload to the radio interface of the vRSU Network Application and checks that its content is correctly inserted into the vRSU Network Application Local Dynamic Map (LDM).	Pass/Fail	Developed
System initiation	Verify the system initiation – the C-ITS stack is up and reporting as running	PASS/FAIL	Developed
Stability of the service, C-ITS congestion	To verify the stability of the service while congestion scenario is introduced. Under high load, a C-ITS message originated from the UE is received	PASS/FAIL	In design
C-ITS in-coverage	A C-ITS message originated from the UE within the coverage zone of the vRSU must be received by other nodes	PASS/FAIL	In Development
C-ITS out-of-coverage	A C-ITS message originated from the UE out of the coverage zone of the vRSU must not be received by other nodes	PASS/FAIL	In Development
Application service continuity	Send sequence of piloting Cooperative Awareness Messages (CAM) to validate E2E connectivity	PASS/FAIL	In design
Decentralized services	Testing the successful trigger of Decentralized Environmental Notification Message (DNEM). Check that the message is correctly sent to the radio interface.	PASS/FAIL	In design

6.2.3 NETWORK APPLICATION 3: C-ITS STATION NETWORK APPLICATION

C-ITS Network Application initial test plan is presented in *Table 11*:

Table 11 C-ITS Network Application initial test plan

C-ITS Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model	Pass/Fail	Developed
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In design
Vertical specific tests: cross vertical			
E2E Packet Data Rate	Verify E2E Packet Data Rate of both Uplink and Downlink from the view of Network Application	1. Uplink >100 kbps for a single UE - Depending 2. Downlink >100 kbps for a single UE – Depending	In design
E2E Packet Latency Core Network Application	Verify E2E Packet Latency per path from the view of Network Application	<50 ms for a single UE	In design
E2E Packet Loss	Verify per communication path E2E Packet Loss from the view of Network Application	<0.025 %	In design
Network Application specific tests			
Cooperative Services	Testing the successful forwarding of a Cooperative Awareness Messages (CAM) by the C-ITS Network Application between two ITS stations in the same geographical area.	PASS/FAIL	Developed
System initiation	Verify the system initiation – the C-ITS stack is up and reporting as running	PASS/FAIL	Developed
Stability of the service, C-ITS congestion	To verify the stability of the service while congestion scenario is introduced. Under high load, a C-ITS message	PASS/FAIL	In design

	originated from the UE is received		
C-ITS in-coverage	A C-ITS message originating from the UE within the coverage zone of the vRSU must be received by other nodes	PASS/FAIL	In Development
C-ITS out-of-coverage	A C-ITS message originated from the UE out of the coverage zone of the vRSU must not be received by other nodes	PASS/FAIL	In Development
Application service continuity	Send sequence of piloting CAM to validate end-to-end connectivity	PASS/FAIL	Developed
Decentralized services	Testing the successful trigger of Decentralized Environmental Notification Message (DNEM).	PASS/FAIL	In design

6.2.4 NETWORK APPLICATION 4: MULTI-DOMAIN MIGRATION NETWORK APPLICATION

Multi-domain migration Network Application initial test plan is presented in *Table 12*:

Table 12 Multi-domain migration Network Application initial test plan

Multi-domain migration Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model.	Pass / Fail	Developed
19	Follows 3GPP security definitions and recommendations	Pass / Fail	In design
Vertical specific tests: automotive vertical			
OBU 5G network register	This test validates that the OBU of the vehicle can effectively register in the 5G network	Pass / Fail	In design
OBU 5G network connectivity	This test validates that the OBU of the vehicle has 5G connectivity	Pass / Fail	In design

OBU 5G handover	This test validates that the OBU of the vehicle can effectively handover among gNBs in the 5G network	Pass / Fail	In design
Vehicular network monitoring	This test validates that the application server can consume monitoring and telemetry data from the vehicular network performance	Pass / Fail	In design
Application service continuity	This test validates that the application running in the vehicle does not interrupt its service after a handover	Pass / Fail	In design
System initiation	Verify the system initiation - the modules are up and reporting as running	Pass / Fail	In design
C-ITS uplink communication	A C-ITS message originated from the UE is received by other nodes	Pass / Fail	In design
C-ITS downlink communication	A C-ITS message originated from an external server is received by other nodes	Pass / Fail	In design
C-ITS congestion	Under high traffic load, a C-ITS message originated from the UE is received by other nodes	Pass / Fail	In design
C-ITS coverage	A C-ITS message originated from the UE out of the coverage zone of the vRSU is not received by other nodes	Pass / Fail	In design
C-ITS edge communication	A C-ITS message originated from a Network Application deployed on the edge is received by other nodes	Pass / Fail	In design
Network Application specific tests			
Simple HTTP request	Simple HTTP request to validate the functioning of the service	HTTP 200 OK	Developed
HTTP Burst request	HTTP burst request to validate the functioning of the service	HTTP 200 OK for all the burst	In design
Migration detection	Introduction of messages that makes the Network Application detect a domain change	The Network Application detect the domain change	In design

New vOBU instantiation	Notify the manager to create a new vOBU in the new domain	The Manager instantiate a new vOBU	In design
Traffic rerouting	The traffic is directly rerouted to the OBU meanwhile the new vOBU is created	The traffic is rerouted to the vOBU, there is no service discontinuity	In design
Traffic rerouting through new vOBU	The traffic is rerouted through the new vOBU	The traffic uses the new vOBU route	In design

6.2.5 NETWORK APPLICATION 5: VEHICLE-TO-CLOUD (V2C) REAL-TIME COMMUNICATION NETWORK APPLICATION

V2C RTC Network Application initial test plan is presented in *Table 13:*

Table 13 V2C RTC Network Application initial test plan

V2C RTC Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model.	Pass/Fail	Developed
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In development
Vertical specific tests: cross vertical			
5G modem register and attach	The test validates the 5G modem) can register and attach to the 5G network	Pass/Fail	In development
E2E Packet Data Rate	Verify E2E Packet Data Rate of both Uplink and Downlink from the view of Network Application	1. Uplink >50 Mbps 2. Downlink >100 Mbps	In development
E2E Packet Latency	Verify E2E Packet Latency of both the UP and Control Plane (CP) from the view of Network Application	1. UP <4 ms 2. CP <20 ms	In development
E2E Packet Loss	Verify E2E Packet Loss of both Uplink and Downlink from the view of Network Application	1. Uplink <0.025 % 2. Downlink <0.025 %	In development

E2E Packet Jitter	Verify E2E Packet Jitter of both the UP and CP from the view of Network Application	1. UP <1 ms 2. CP <10 ms	In development
E2E Frame Loss	Verify E2E Frame Loss of both Uplink and Downlink from the view of Network Application	<50 frame skips per hour	In development
Network Application specific tests			
System initiation	Verify the system initiation - the modules are up and reporting as running	PASS/FAIL	Developed
Streamer and connector connection	The streamer and connector are connected to relay and node and reporting as connected	PASS/FAIL	Developed
System synchronization	The system is synchronized using the cellular network	PASS/FAIL	Developed
Connectivity to reporting service	Connectivity to reporting service is established	PASS/FAIL	Developed
Beginning of the video stream	Beginning of the video stream – the streamer is generating a video pattern pushed through the streamer and 5G system to the relay and node (terminated and measured)	PASS/FAIL	Developed
vOBU release	Simulated release request from an OBU asking for the release of the used vOBU	vOBU release	In design
Stability of the service	To verify the stability of the service while video BW is being changed according to the predefined pattern (between 2Mbps to 20Mbps)	PASS/FAIL	In design

6.2.6 NETWORK APPLICATION 6: REMOTE HUMAN DRIVING NETWORK APPLICATION - TELEOPERATION FOR ASSISTING VEHICLES IN COMPLEX SITUATIONS

Remote Human Driving Network Application - Teleoperation for assisting vehicles in complex situations initial test plan is presented in *Table 14:*

Table 14 Remote Human Driving Network Application - Teleoperation for assisting vehicles in complex situations initial test plan

Remote Human Driving Network Application - Teleoperation for assisting vehicles in complex situations Network Application initial test plan			
Test	Description	Expected results	Current Status
Network Application certification tests			
4	Follows NFV model	Pass/Fail	Developed
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In development
Vertical specific tests: cross vertical			
5G modem register and attach	The test validates the 5G modem) can register and attach to the 5G network	Pass/Fail	In development
E2E Packet Data Rate	Verify E2E Packet Data Rate of both Uplink and Downlink from the view of Network Application	1. Uplink >50 Mbps 2. Downlink >100 Mbps	In development
E2E Packet Latency	Verify E2E Packet Latency of both the UP and CP from the view of Network Application	1. UP <4 ms 2. CP <20 ms	In development
E2E Packet Loss	Verify E2E Packet Loss of both Uplink and Downlink from the view of Network Application	1. Uplink <0.025 % 2. Downlink <0.025 %	In development
E2E Packet Jitter	Verify E2E Packet Jitter of both UP and CP from the view of Network Application	1. UP <1 ms 2. CP <10 ms	In development
E2E Frame Loss	Verify E2E Frame Loss of both Uplink and Downlink from the view of Network Application	<50 frame skips per hour	In development
Network Application specific tests			
System initiation	Verify the system initiation - the modules are up and reporting as running	PASS/FAIL	Developed

Streamer and connector connection	The streamer and connector are connected to relay and node and reporting as connected	PASS/FAIL	Developed
System synchronization	The system is synchronized using the cellular network	PASS/FAIL	Developed
Connectivity to reporting service	Connectivity to reporting service is established	PASS/FAIL	Developed
Beginning of the video stream	Beginning of the video stream – the streamer is generating a video pattern pushed through the streamer and 5GS to the relay and node (terminated and measured)	PASS/FAIL	Developed
vOBU release	Simulated release request from an OBU asking for the release of the used vOBU	vOBU release	In design
Stability of the service	To verify the stability of the service while video BW is being changed according to the predefined pattern (between 2Mbps to 20Mbps)	PASS/FAIL	In design

6.2.7 NETWORK APPLICATION 7: EFFICIENT MEC HANDOVER NETWORK APPLICATION

The Efficient MEC Handover (EMHO) Network Application would follow the two mandatory tests (4,19) as per the Network Application certification requirements[3]. In addition, there are a few test cases under a design phase that are specific to this Network Application to test its functionality. These Network Application-specific test cases would focus on the availability of the Representational State Transfer (REST) interfaces of the Network Application to be accessed by the monitoring system and the supported Network Application(s). Also, it will test the basic functionality of the Network Application to predict the mobile handover probability. *Table 15* lists the detail of the test cases.

Table 15 EMHO Network Application initial test plan

EMHO Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model	Pass/Fail	Pass
5	May expose APIs to be consumed by other service	Pass/Fail	Pass

11	May interact with the 5GS by consuming 5GS's APIs, if the 5GS allows.	Pass/Fail	In design
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In design
Network Application specific tests			
Simple HTTP request	Simple HTTP request to validate the functioning of the service	HTTP 200 OK	Complete
HTTP GET request	This test validates the Network Application has REST interfaces of the EMHO Network Application that are accessible for the supported/enhanced Network Application using the 5G network	HTTP 200 OK	Complete
Dummy data push	Use REST interface to send a dummy radio monitoring data to the Network Application	Prediction probabilities as JSON	Complete
Network Application prediction based on provided input data	This is the case when another Network Application/service sends a JSON file with RSRP, RSRQ.. values and gets back a prediction.	Prediction probabilities as JSON	Complete
RSRP and Path loss by UE (5G readiness)	Get the RSRP and path loss values from a defined UE with respect to the serving cell.	RSRP and Path loss values as JSON	In design
Network Application prediction based on extracted UE data from the NEF	This is the case when another Network Application/service requests an ML prediction of a specific UE ID.	Prediction probabilities as JSON	In design

6.2.8 NETWORK APPLICATION 8: PRIVACYANALYZER NETWORK APPLICATION

The PrivacyAnalyzer cross-vertical Network Application shall follow the compulsory 5GASP-C tests 4 and 19.

The Network Application specific tests assess (i) the accuracy of the privacy service using own data sets and (ii) the reliability of the service when injecting large volumes of data. *Table 16* lists the detail of the test cases.

Table 16 PrivacyAnalyzer Network Application initial test plan

PrivacyAnalyzer Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Should follow the NFV model	Pass/Fail	Pass
19	Should follow relevant 3GPP security definitions and recommendations	Pass/Fail	In design
Network Application specific tests			
Accuracy	Emulated client requests via a python container which sends data from our own data set	Accuracy of privacy assessment (F1 score) more than 85%	Complete
Reliability	Ingestion of large volumes of client requests and monitoring via Command line tool (kubectl) the status of the PrivacyAnalyzer backend (privacy backend and mongoDB cluster)	Pass/Fail	In design

6.2.9 NETWORK APPLICATION 9: 5G ISOLATED OPERATION FOR PUBLIC SAFETY NETWORK APPLICATION (5G IOPS NETWORK APPLICATION)

The Isolated Operations for Public Safety (IOPS) Network Application will follow selected mandatory tests (4, 19) to comply with 5GASP's Network Application certification requirements[3]. Additionally, IOPS Network Application will be tested against selected PPDR vertical tests available at ININ's testbed, specifically targeting PPDR IOPS operation and UE connectivity over the PPDR IOPS slice. Initially, the tests were manually executed. At this moment, first tests are already implemented in robot/Jenkins framework while the rest are under implementation. Also, some Network Application specific test cases were specified, mainly to test the basic functionality and operation of the IOPS Network Application and test performance of the PPDR slice provided by the Network Application. Currently, Network

Application basic functionality tests are already implemented in robot/Jenkins framework while performance tests were executed manually with ININ's qMON monitoring tool and are planned to be automated in the next phase (*Table 17*).

Table 17 Isolated Operations for Public Safety Network Application initial test plan

Isolated Operations for Public Safety Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model	Pass/Fail	In design/pending
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In design/pending
Vertical specific tests: PPDR vertical			
PPDR UE (smart phone) - network connectivity	This test validates that the 5G UE (smart phone) can reach the public services over the PPDR network	Pass/Fail	Pass/manual
PPDR UE (5G gateway) - network connectivity	This test validates that the 5G UE (gateway) can reach the public services over the PPDR network	Pass/Fail	Pass/Jenkins
PPDR IOPS - failure detection time	This test validates that the 5G PPDR slice IOPS operation meets the requirements to detect 5G primary CN connection failure in under certain time	Pass/Fail (< 30 seconds)	Pass/manual; Pending implementation
PPDR IOPS - switchover	This test validates that the 5G PPDR slice provides IOPS functionality (i.e., gNB switch to IOPS CN after connection to primary CN fails)	Pass/Fail	Pass/manual; Pending implementation
PPDR IOPS - switchover time	This test validates that the IOPS operation meets the requirements to switch to local (IOPS) core in under certain time	Pass/Fail (< 300 seconds)	Pass/manual; Pending implementation
PPDR IOPS - restoration time	This test validates that the IOPS operation meets the requirements to restore connection to primary CN in under certain time	Pass/Fail (< 300 seconds)	Pass/manual; Pending implementation

PPDR IOPS - UE local IOPS network connectivity (smart phone)	This test validates that the 5G UE (smart phone) can reach the local services over the IOPS PPDR network	Pass/Fail	Pass/manual
PPDR IOPS - UE local IOPS network connectivity (5G gateway)	This test validates that the 5G UE (gateway) can reach the local services over the IOPS PPDR network	Pass/Fail	Pass/Jenkins
Network Application specific tests			
IOPS gNB Component readiness	Send HTTP request to validate the functionality of the service	HTTP 200 OK	Pass/Jenkins
IOPS CN Component readiness	Send HTTP request to validate the functionality of the service	HTTP 200 OK	Pass/Jenkins
Web test	Send HTTP request to validate the functionality of the configured service (e.g. google.com)	HTTP 200 OK	Pass/manual via qMON; Pending implementation
DNS test	Send DNS request to validate the functionality of the service	DNS response = Pass DNS reply time < 30 ms	Pass/manual via qMON; Pending implementation
Ping test	Send sequence of Ping requests to validate E2E connectivity and to measure response time	< 20 ms	Pass/manual via qMON; Pending implementation
IP throughput download test	Download a specific amount of data to estimate download data rate	> 60 Mbit/s	Pass/manual via qMON; Pending implementation
IP throughput upload test	Upload a specific amount of data to estimate upload data rate	> 180 Mbit/s	Pass/manual via qMON; Pending implementation
Packet loss	Transfer a specific amount of data to estimate packet loss	$< 10^{-6}$	Pass/manual via qMON; Pending implementation

6.2.10 NETWORK APPLICATION 10: VEHICLE ROUTE OPTIMIZER NETWORK APPLICATION

The Vehicle Route Optimizer Network Application would follow the two mandatory tests (4,19) as per the Network Application certification requirements[3]. In addition, there are a few test cases being designed specific to the Network Application to test the functionality. These Network Application specific testcases would focus on the availability of the REST interfaces of the Network Application. Also, it will test the basic functionality of the Network Application to create a "ride request" and expect a valid response. The *Table 18* lists the detail of the testcases.

Table 18 VRO Network Application initial test plan

VRO Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model	Pass/Fail	Developed/ Passed
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In design
Network Application specific tests			
Simple HTTP request	Simple HTTP request to validate the functioning of the service	HTTP 200 OK	Developed/ Passed
HTTP GET request	This test validates the Network Application has REST interfaces of the VRO Network Application that are accessible for the supported/enhanced Network Application using the 5G network	HTTP 200 OK	Developed/ Passed
HTTP POST request	Use REST interface to send a dummy "ride request" data to the Network Application	Valid response as JSON	Developed/ Passed

6.2.11 NETWORK APPLICATION 11: FIRE DETECTION AND GROUND ASSISTANCE USING DRONES (FIDEGAD)

The FIDEGAD Network Application would follow the compulsory tests, as per the 5GASP Network Application certification requirements[3]. Also, within the specific context of its functionality, several Network Application-oriented tests are introduced. Namely, an initial test is developed that validates the availability of the web-based dashboard of Network Application. After the E2E availability is established through the previous test, the proper

functionality of the recognition services is put under test. Specifically, the recognition service is provided with a predetermined video stream and is tested against specific frames that would trigger the fire detection algorithm and others that would not, respectively.

A summary of the described test cases is illustrated in *Table 19*.

Table 19 Fire Detection and Ground Assistance using Drones (FIDEGAD) Network Application initial test plan

Fire Detection and Ground Assistance using Drones (FIDEGAD) Network Application initial test plan			
Test	Description	Expected results	Current status
Network Application certification tests			
4	Follows NFV model	Pass/Fail	Developed/ Passed
19	Follows 3GPP security definitions and recommendations	Pass/Fail	In design
Network Application specific tests			
Web test	Send HTTP request to validate the availability of the web-based Network Application's dashboard	Pass/Fail	Developed/ Passed
Recognition service functionality test	Verify that recognition services are functioning properly by providing predefined frames	Pass/Fail	Developed/ Passed
Integration with 5G System test	Verify that the Network Application is authenticated/authorized with 5G services	Pass/Fail	In design

7 Preliminary certification results

This section presents some preliminary certification results. As presented in Section 2.1, the baseline requirements for a Network Application to be certified are linked to Network Application Certification definitions 4 and 19. Definition 4 states that a Network Application must follow the NFV model. This definition is tested when a Network Application is onboarded to 5GASP NODS. Thus, all Network Applications are already certified according to such definition.

On the other hand, definition 19 states that a Network Application should follow all the relevant 3GPP security definitions and recommendations. Section 4.2 already presented the test cases defined by 5GASP to address definition 19.

As an initial effort towards the certification of a 5GASP Network Application, the already implemented test cases addressing definition 19 were performed on Network Application 1 – vOBU. These test cases are listed in *Table 20*.

Table 20 Network Application 1 - Certification Test Cases

Certification Definition ID	Test Case ID	Test Case
19	2	VNFs should use a security-group offered by testbed
19	3	Openstack Port Security
19	4	SSL Protected APIs
19	5	Secure SSH Credentials
19	7	Open Ports
19	8	SSH Server Security
19	9	NEF Authentication

Even though 5GASP's certification entity has not been developed, one may rely on the results of the validation of Network Application 1 to infer its certification status. Network Application's 1 validation tests are showcased in *Figure 24.*

Tests Performed

Test ID	Test Name	Start	End	Test Status	Test Description	Test Log	Test Report
1	Open Ports	2023-03-17 14:27:31	2023-03-17 14:27:32	Passed	Check if the Aggregator's open ports are the ones desired	Test Log	Test Report
2	Open Ports	2023-03-17 14:27:36	2023-03-17 14:27:38	Passed	Check if the Manager's open ports are the ones desired	Test Log	Test Report
3	Open Ports	2023-03-17 14:27:41	2023-03-17 14:27:43	Passed	Check if the vOBU's open ports are the ones desired	Test Log	Test Report
4	Openstack Port Security	2023-03-17 14:27:51	2023-03-17 14:27:51	Passed	Test Port Security	Test Log	Test Report
5	SSH Server Security	2023-03-17 14:27:59	2023-03-17 14:27:59	Failed	Test SSH Server Security - Aggregator VNF	Test Log	Test Report
6	SSH Server Security	2023-03-17 14:28:03	2023-03-17 14:28:04	Failed	Test SSH Server Security - Manager VNF	Test Log	Test Report
7	SSH Server Security	2023-03-17 14:28:07	2023-03-17 14:28:08	Failed	Test SSH Server Security - vOBU VNF	Test Log	Test Report
8	SSL Protected APIs	2023-03-17 14:28:20	2023-03-17 14:28:21	Failed	SSL Audit - Aggregator's API	Test Log	Test Report
9	SSL Protected APIs	2023-03-17 14:28:25	2023-03-17 14:28:25	Failed	SSL Audit - Manager's API	Test Log	Test Report
10	SSL Protected APIs	2023-03-17 14:28:29	2023-03-17 14:28:30	Failed	SSL Audit - vOBU's API	Test Log	Test Report
11	Secure SSH Credentials	2023-03-17 14:28:40	2023-03-17 14:28:42	Failed	Test the the credentials of the Aggregator VNF	Test Log	Test Report
12	Secure SSH Credentials	2023-03-17 14:28:46	2023-03-17 14:31:29	Passed	Test the the credentials of the Manager VNF	Test Log	Test Report
13	Secure SSH Credentials	2023-03-17 14:31:41	2023-03-17 14:37:01	Passed	Test the the credentials of the vOBU VNF	Test Log	Test Report
14	NEF Authentication	2023-03-17 14:37:12	2023-03-17 14:37:13	Passed	Test if the NetApp can authenticate withing NEF	Test Log	Test Report
15	dev-defined-api_request_test	2023-03-17 14:37:22	2023-03-17 14:37:22	Passed	Test if the Manager's API is ready	Test Log	Test Report
16	dev-defined-api_request_test	2023-03-17 14:37:31	2023-03-17 14:37:31	Passed	Test if the Aggregator's API is ready	Test Log	Test Report
17	dev-defined-database_ready_test	2023-03-17 14:37:40	2023-03-17 14:37:40	Passed	Check if the Aggregator's Database is Ready	Test Log	Test Report
18	dev-defined-database_ready_test	2023-03-17 14:37:49	2023-03-17 14:37:49	Passed	Check if the vOBU's Database is Ready	Test Log	Test Report
19	dev-defined-obu_data_consumption_test	2023-03-17 14:38:01	2023-03-17 14:38:35	Passed	Check if the OBU's produced data can be consumed	Test Log	Test Report

Figure 24 Network Application1 – Performed Test Cases

Considering no other certification testing scopes were addressed during the validation of Network Application1, the spider graph Network Application shall be similar to the one presented in *Figure 25*.

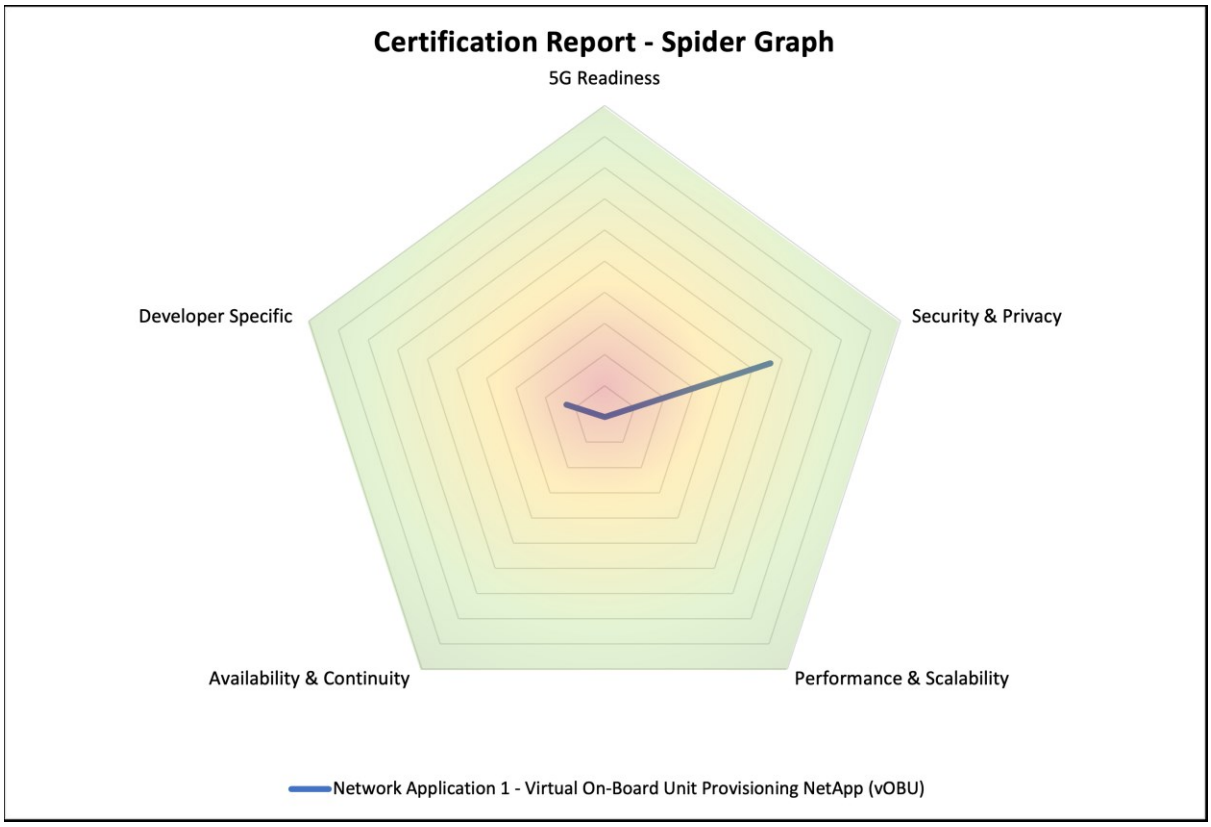


Figure 25 Network Application 1 - Certification Spider Graph

While this section presents an overview of our efforts towards the certification of 5GASP Network Applications, much effort will still have to be made to achieve the certification of all 5GASP Network Applications. As future directions, we expect having all 5GASP Network Applications undergoing our Certification Process by the end of Q2 2023. Furthermore, by this date, 5GASP also expects to have its certification entity developed. This entity will be responsible for certifying Network Applications based on the outcomes provided by 5GASP's Validation Service. Moreover, it will create the certificates that shall be provided to the Network Application developers, so they can prove their Network Applications are compliant with 5GASP's certification.

8 Conclusions

The main goal of this deliverable is to define the certification process and all tests used to certify each Network Application involved in the 5GASP project. As such, there are three primary outcomes: (i) further elaboration on the Network Applications' certification process; (ii) further elaboration on the definition of the tests used in this process; and (iii) definition of the *tailor*-made tests that will be used to further test and validate each Network Application. The deliverable also presents preliminary certification results of the Network Applications contributed by the participating consortium partners in the project.

In more detail, Section 6.1 presents the preliminary test results that have been already performed in all six testbed sites of the project. Specifically, each testbed owner has presented the tests that have been locally instantiated and executed in their infrastructure so far, together with initial obtained results.

To certify a Network Application, besides the defined global tests, Network Application developers may choose to onboard their own tests and validate the behaviour and functionality of their Network Application. The certification process can readily divulge the results of their execution and make available all the log and report files collected during the testing and validation phase. This allows a *third-party entity* to know *precisely* which tests were executed to validate a Network Application, thus increasing the trust regarding this Network Application. The 5GASP consortium considers these developer-defined tests as a crucial element of the certification process. Thus, we analyse each Network Application in Section 2, and list a collection of tests that can be used to validate its functionality and behaviour.

Overall, this deliverable contains the detailed current status of the 5GASP certification process, including certification test case implementation and next steps on 5GASP certification process. Regarding preliminary certification results performed, they will be improved and extended in the next deliverable, namely D5.5. The latter will expose the final results of the testing and certification for the 5GASP Network Applications.

Appendix A

Text Version Network App MiniAPI

NetworkApp-MiniAPI

5GASP NetworkApp Control Mini API
More information: https://helloreverb.com
Contact Info: info@5gasp.eu
Version: 1.0.0
BasePath:/CROSS_1/5GASP_NetworkAppControl_MiniAPI/1.0.0
Apache 2.0
http://www.apache.org/licenses/LICENSE-2.0.html

Access

Methods

[Jump to Models]

Table of Contents

Default

- post /abort
- post /configStream
- get /info
- get /report
- post /start

Default

Up

(abortPost)
Aborts a previously started stream (this command blocks until the operation is aborted)
Query parameters
runId (optional)
Query Parameter — ID referencing the started test run (from /start directive)
Responses
200

Test was aborted
412

No configuration for test found
500
Other server error, cannot abort
size=1 width="100%" noshade style='color:#DDDDDD' align=center>

Up

(**configStreamPost**)
Configures a test data stream in preparation of its start
Consumes
This API call consumes the following media types via the Content-Typerequest header:

- `application/json`

Request body
body StreamConfig (optional)
Body Parameter —
Return type
Integer
Example data
Content-Type: application/json

```
0
```

Produces
This API call produces the following media types according to the Acceptrequest header; the media type will be conveyed by the Content-Typeresponse header.

- `text/plain`

Responses
201
item created, returning ID Integer
400
cannot create stream,
409
invalid input, values out of bounds
size=1 width="100%" noshade style='color:#DDDDDD' align=center>

Up

get info about NetworkApp (**info**)
To start the communication, client can ask the NetworkApp about its details
Return type
NetworkAppInfo
Example data
Content-Type: application/json

```
{  "maxStreams" : 50,  "maxTotalBandwidthUp" :
300000,  "maxTotalBandwidthDown" : 300000,  "name" : "Autonomous Driving
NetworkApp",  "version" : "3.2.1",  "manufacturer" : "ACME Corporation"}
```

Produces

This API call produces the following media types according to the Acceptrequest header; the media type will be conveyed by the Content-Typeresponse header.

- `application/json`

Responses

200

info and config details of networkApp NetworkAppInfo

400

no info available

size=1 width="100%" noshade style='color:#DDDDDD' align=center>

Up

(reportGet)

retrieve results data from previously executed test run

Query parameters

runId (optional)

Query Parameter — ID referencing the started test run (from /start directive)

Return type

TestResults

Example data

Content-Type: application/json

```
{  "minAppStreamHealth" : 12,  "tputUp" : [ 1, 1 ],  "dataLostUp" : [ 5, 5
],  "latencyMaxDown" : [ 3, 3 ],  "cpuLoadAvg" : [ 20, 20 ],  "duration" :
0,  "tputDown" : [ 6, 6 ],  "latencyMaxUp" : [ 9, 9
],  "maxAppStreamHealth" : 10,  "latencyAvgDown" : [ 7, 7
],  "avgAppStreamHealth" : 73,  "dataLostDown" : [ 5, 5 ],  "latencyAvgUp"
: [ 2, 2 ],  "cpuLoadMax" : [ 41, 41 ]}
```

Produces

This API call produces the following media types according to the Acceptrequest header; the media type will be conveyed by the Content-Typeresponse header.

- `application/json`

Responses

200

Results retrieved TestResults

409

Test is still running

412

No configuration for test found

size=1 width="100%" noshade style='color:#DDDDDD' align=center>

Up

(startPost)

Starts a previously configured stream

Query parameters

configId (optional)

Query Parameter —

duration (optional)
Query Parameter —
Return type
Integer
Example data
Content-Type: application/json

```
0
```

Produces
This API call produces the following media types according to the Acceptrequest header; the media type will be conveyed by the Content-Typeresponse header.

- `text/plain`

Responses
202
Test was started, no response yet Integer
400
Parameter error
409
Another test is already running
412
No configuration for test found
size=1 width="100%" noshade style='color:#DDDDDD' align=center>

Models

[Jump to Methods]

Table of Contents

1. `NetworkAppInfo`
2. `StreamConfig`
3. `TestResults`

`NetworkAppInfo` Up

name
String
example: Autonomous Driving NetworkApp
version
String
example: 3.2.1
manufacturer
String
example: ACME Corporation
maxStreams
Integer maximum number of simultaneous streams that can be created

example: 50

maxTotalBandwidthDown
Integer Maximum total bandwidth that can be configured for downstream (from NetworkApp to UE), in kilobits per second (1 kbit/s = 1024 bits/s)
example: 300000
maxTotalBandwidthUp
Integer Maximum total bandwidth that can be configured for upstream (from UE to NetworkApp), in kilobits per second (1 kbit/s = 1024 bits/s)
example: 300000

`StreamConfig` Up

configuration parameters for streams; note that in future versions, additional parameters such as protocol type (http, https, etc.), object length, burstiness parameters could be added
numberofStreams (optional)
Integer number of simultaneous streams to be created
example: 50
tputTotalDown
Integer Total bandwidth per second to be sent downstream (from NetworkApp to UE), in kilobits per second; this is split between the number of streams configured
example: 300000
tputTotalUp
Integer Total bandwidth per second to be sent upstream (from UE to NetworkApp), in kilobits per second; this is split between the number of streams configured
example: 300000

`TestResults` Up

set of throughput test results
duration
Integer actual test run duration (seconds)
tputDown
array[Integer] Downstream throughput per stream (in bytes) for the total test duration (not per second)
tputUp
array[Integer] Upstream throughput per stream (in bytes) for the total test duration (not per second)
dataLostUp (optional)
array[Integer] Upstream data lost per stream (in bytes) for the total test duration (not per second)
dataLostDown (optional)
array[Integer] Downstream data lost per stream (in bytes) for the total test duration (not per second)
latencyAvgUp (optional)
array[Integer] Upstream average latency per stream (in microseconds)
latencyAvgDown (optional)

array[Integer] Downstream latency per stream (in microseconds)

latencyMaxUp (optional)
array[Integer] Upstream maximum latency per stream (in microseconds)
latencyMaxDown (optional)
array[Integer] Downstream maximum per stream (in microseconds)
cpuLoadAvg (optional)
array[Integer] array of cpu (thread) load values in percentage, for each cpu core used by the application, averaged across the test duration
cpuLoadMax (optional)
array[Integer] array of cpu (thread) load values in percentage, for each cpu core used by the application, maximum value reached at any time during the test duration
avgAppStreamHealth (optional)
Integer abstract networkApp health value between 0 (app down) to 100 (app transferred all data in perfect health), averaged across the test duration
minAppStreamHealth (optional)
Integer abstract networkApp health value between 0 (app down) to 100 (app transferred all data in perfect health), worst value during the test duration
maxAppStreamHealth (optional)
Integer abstract networkApp health value between 0 (app down) to 100 (app transferred all data in perfect health), best value during the test duration

References

[1] 5GASP, "D5.1 Initial Report on Test Plan Creation and Testing Methodologies," September 2021, https://www.5gasp.eu/assets/documents/deliverables/D5.1%20Initial%20Report%20on%20Test%20Plan%20Creation%20and%20Testing%20Methodologies.pdf

[2] 5GASP, "D5.2 Integration guide and API reference manual," January 2022, https://www.5gasp.eu/assets/documents/deliverables/D5.2%20-%20Integration%20guide%20and%20API%20reference%20manual.pdf

[3] 5GASP, "D5.3 Development of testing tools and framework for the Automotive and PPDR Verticals", April 2022, https://www.5gasp.eu/assets/documents/deliverables/D5.3%20Development%20of%20testing%20tools%20and%20framework%20for%20the%20Automotive%20and%20PPDR%20Verticals.pdf

[4] 5GASP, "D6.2 Interim progress report on Network Applications Community & Certification process", December 2022