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Final Report for the Network Application Certification

Abstract

This deliverable confirms and concludes the certification process and all the test procedures that the certification of each Network Application has involved up until the end of the project. It encompasses three primary outcomes: the final description of the Network Application's certification process, the final definition of the tests used in the latter-mentioned process, including the Network Applications' developer-defined tests and testing procedures, and, most importantly, the final demonstration for the structure and process of certifying Network Applications, with the latest results of certification.

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Disclaimer

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Executive Summary

This deliverable report is the final iteration in a series of five deliverable reports scheduled for M9, M12, M13, M21 and M39 respectively (this current iteration, postponed from an initial delivery schedule of M35). The present final report provides updates according to the progress of WP5 tasks and milestones, the definition and design of testing procedures, and their implementation, through the CI/CD pipeline, on the 5GASP Platform, towards the certification of Network Applications. Respective to the testing and certification pipeline and format, the consortium has taken into consideration the feedback received during the interim review process of June 2023, to change and improve the certification format and testing pipeline and classification, both to attract more interest from other ICT-41 projects and industry, but also to provide a more comprehensive platform for development and 5G certification purposes, as a showcase of the integration potential with the 5G and RAN ecosystem. The report also showcases the results that all of the Network Applications have achieved in the testing and certification pipeline mentioned above, proving the achievements of all the applications provided through our portal. As final remarks, this report summarizes the maintenance activities of the two different types of 5GASP Network Applications (based of VNFs and CNFs), lessons learned and showcases the understanding of the integration and testing complexity, towards obtaining a more developer-friendly environment.

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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
CIS	Center for Internet Security
SBoM	Software Bill of Materials
CVE	Common Vulnerability and Exposure
NVD	National Vulnerability Database
NIST	National Institute of Standards and Technology
SPDX	Software Package Data Exchange
TC	Linux Traffic Control

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

The purpose of this document is to present the progress, and the final state on three tasks within WP5, namely, Task 5.1 on “Definition and Development of NApp Onboarding”, Task 5.2 on “Network Interoperability, Testing Methodology and Validation”, and Task 5.3 regarding the “NApp CI/CD Test Execution and Documentation”.

With D5.4 [1] as the precursor and incipient work on testing and certification, the purpose of this document is to demonstrate the progress made on the testing and certification done on the consortium’s (and others’) Network Applications, toward finalizing the project’s WP5 Task 5.3, and providing proof of the full Network Application Store, NODS, CI/CD and Certification Platforms’ full integration. In addition, this document will provide an overview on all the testing axes, test descriptions and descriptors and certification pipeline, provided through the 5GASP platform.

To summarize, this deliverable encompasses three primary outcomes: (i) final description of the Network Application's certification process, (ii) final definition of the tests used in this process, including the Network Applications' developer-defined test upload and accepted testing procedures, and (iii) final demonstration for the structure and process of certifying Network Applications.

1.2 Approach and Methodology

This document mainly aims to show the conclusion of 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 [2] 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 [3]. These two deliverables introduced the architecture and the features of the Validation Service that is used to certify a Network Application.

D5.2 [3] 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 [2], could be deployed in a distributed paradigm that would enable the execution of validation pipelines across all 5GASP's Testbeds.

Finally, D5.3 [4] 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 concludes on the definitions and results of the Certification Process, showcasing the achievements in regard to this operation and further elaborating its workflow, towards the onboarding and certification of other 5G Network Apps. To certify a Network Application, besides the defined global tests, Network Application developers may choose to onboard their own tests and validate the behavior 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 analysis 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 3 main categories: Bronze, Silver and Gold

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 results of the testing that has been performed in all the testbeds of the project: Murcia, Aveiro, Bristol, Patras, Bucharest and Ljubljana sites. Subsection 6.2 presents the test plans that have been designed for each of the eleven Network Applications involved in the project:

1. Virtual On-Board Unit provisioning Network Application (vOBU);
2. Virtual RoadSide Unit provisioning Network Application (vRSU);
3. ITS station Network Application;
4. Multi-domain Migration Network Application;
5. Vehicle-to-Cloud (V2C) Real-Time Communication Network Application;
6. Remote Human Driving Network Application - Teleoperation for assisting vehicles in complex situations;
7. Efficient MEC handover Network Application;
8. PrivacyAnalyzer Network Application;
9. 5G Isolated Operation for Public Safety Network Application (5G IOPS Network Application);
10. Vehicle Route Optimizer Network Application;
11. Fire detection and ground assistance using drones (FIDEGAD).

Chapter 7 presents the 5GASP Network Applications' certification results.

Finally, Chapter 8 provides conclusions and lessons learned.

2 Network Applications Certification Definitions

5G can fundamentally enable the applications to improve quality of life via unprecedented use cases that require high data-rate instantaneous communications, low latency, and massive connectivity. More and more SMEs are innovating their network applications to provide services based on the 5G ecosystem from the network operators. Most SMEs are innovative in software design and development but lack the means to fully test, validate and certify their products across diverse 5G environments. Furthermore, network operators will be challenged to independently assess and validate the various applications individually.

5GASP aims to unlock such a dilemma by creating an automated 5GASP certification (5GASP-C) for Network Applications (NApps). 5GASP-C enables the reproducible and effective tests to reduce the individual validation effort by Network Application developers and operators.

The 5GASP certification is the technical, organizational, and administrative process executed to certify a Network Application. The following parties are involved in the 5GASP-C process.

1. Network Application Applicant

A Network Application Applicant is an equipment manufacturer and/or software provider providing a Network Application supporting the 5GASP requirements, which would like to certificate his Network Application in 5GASP-C platform. There are some activities as follows for the applicant to initialise a certification request, coordinate for the testing, and achieve a certificate.

- Select an authorized testbed which meets the Applicant's needs and schedule a certification testing slot
- Complete Network Application certification application and submit all required supporting documentation
- Submit required materials to the testbed for certification testing
- Coordinate with testbed on monitoring/supporting the certification test execution
- Coordinate with testbed on investigation/debugging of Network Application test issues as required

The Network Application Applicant will have the opportunity to showcase his product along with certifications on the supported software platforms (interoperability) and functionality (as assessed by a 3rd party 5GASP-C).

2. Authorized Testbed

An Authorized Testbed is an independent testbed that has 5GASP's approval to provide test reports for Network Application certification. There are some activities as follows for the

testbed to prepare, schedule, coordinate, execute the testing with Network Application Applicant, and report, escalate the result to Certification Authority.

- Respond promptly to testing inquiries from Applicants
- Coordinate with Applicant to schedule timely testing slot
- Coordinate with Applicant to complete all pre-testing logistics
- Execute formal certification testing
- Review testing results for test environment integrity and accuracy
- Escalate abnormal test findings to 5GASP certification authority for disposition
- Facilitate investigation/debugging of product test issues with Applicant as requested
- Communicate completed test results to the 5GASP certification repository

3. Certification Authority

The Certification Authority is the 5GASP Logo owner and Program Administration of 5GASP Certification. There are some activities as follows for the authority to not only review, approve, arbitrate the testing with Network Application Applicant and Authorized Testbed, but also issue the 5GASP certificate online in a public marketplace portal.

- Review/approve product certification application and supporting documentation
- Collaborate with Testbeds on investigation/disposition of abnormal test findings
- Review testing results for product compliance
- Arbitrate any escalated issues from Testbed and Applicant
- Issue certificate and associated logo
- Maintain certified product listing

5GASP deployed a showcase portal for the registered network applications, 5GASP Network Application Store on the public cloud network. It provides certification information collected automatically during the Network Applications independent testing on the 5GASP-C platform. The below workflow shows the details of 5GASP-C process.

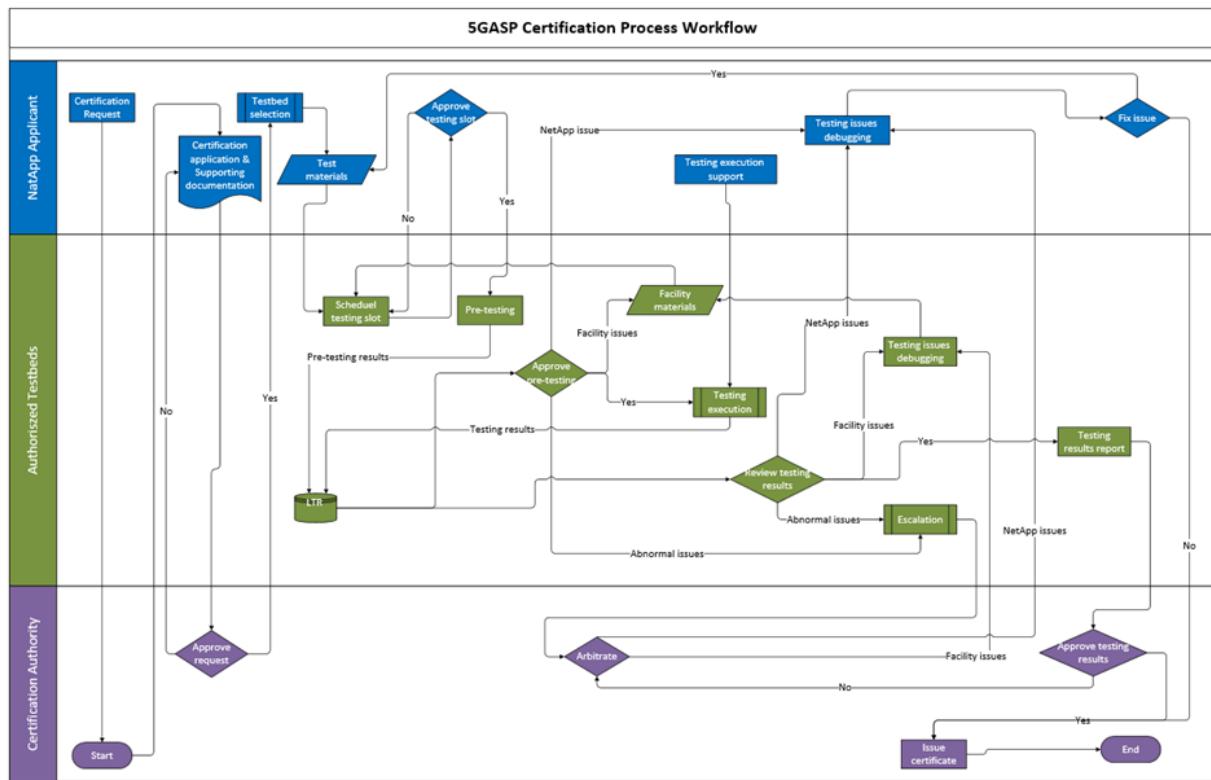


Figure 1 - 5GASP Certification Process Workflow

5GASP-C platform is open for 3rd party Network Application to certify the functionality, performance, security, and connectivity of the application on one or multiple of the authorized Testbeds located on Aveiro (Portugal), Patras (Greece), Bristol (UK), Ljubljana (Slovenia), Bucharest (Romania) and Murcia (Spain).

2.1 Certification Definitions

The certification results are presented in a so-called spider diagram (e.g., see Fig. 2 for reference) with the relevant axes for the 5GASP test domains.

2.1.1 Test Axes

The certification tests are categorized by the test axis (scope) and whether the test is mandatory or conditional mandatory. As the word mandatory implies, these are tests that every Network Application must pass to get a certificate of the minimum grade. Applicants can choose test conditions which yield a set of conditional mandatory tests (D6.3 [5] Section 4.1) to evaluate additional capabilities of their Network Application, thus having a chance at achieving a higher certificate grade. Through different test axes, a Network Application's abilities and performance can be evaluated in detail. The four test axes are as follows:

5G Readiness: This axis determines the readiness of Network Applications for a 5G Network. These tests verify the ability of a Network Application during its operation to communicate, interact and use the Network Exposure Function (NEF) interface and other possible 5GS components.

Security & Privacy: This axis determines a Network Application's security and privacy levels. These tests verify a Network Application's security through tests aligned to 3GPP inherited security recommendations, common penetration testing, and basic NFV segmentation.

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

Availability & Continuity: This axis evaluates the ability of a Network Application to sustain service over time regarding the provided KPIs under different stress scenarios, for example, transmission impairment, long-term burn, service request denial, or downgrade from 5GS. These tests measure the ability of a Network Application to overcome the exceptional circumstances of a 5G network.

2.1.2 Grades and Score Calculation

A 5GASP Certificate can be obtained with one of the following grades, ranking from lowest to highest: Bronze, Silver, and Gold. The grade is determined by a minimum score that must be achieved on each test axis. A Bronze grade is achieved if each axis has a score of at least 1; a silver grade is achieved if each axis has a score of at least 5; and a Gold grade is achieved if each axis has a score of at least 8. If no test was executed on an axis due to applicability, it is excluded from this process.

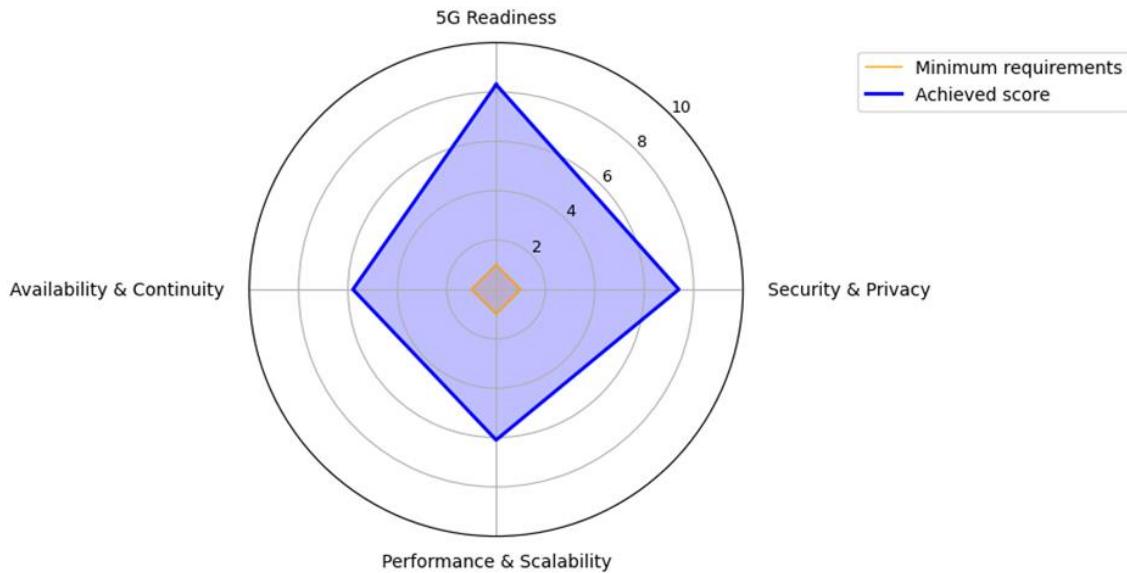


Figure 2 - Certification Spider Diagram

The radar chart above shows an example of a Network Application's achieved axis scores. Such a chart is also included in the certificate document. The scores in this example would result in a silver grade certificate as each axis score is above 5 but not above 8; the exact scores are listed in the table below.

Test Axis	Axis Score
5G Readiness	8.3
Security & Privacy	7.4
Performance & Scalability	6.1
Availability & Continuity	5.8

Table 1 - Test Axes Scoring Table

An axis score is calculated from the test results of the corresponding axis. Mandatory and conditional mandatory tests are considered separately. For mandatory tests, if all tests are passed, the result is 1; otherwise, the result is 0. For conditional mandatory tests, the weighted average of the executed tests is calculated in the following way: The weight of each passed test is summed and the weight of all executed tests is summed. Then, the first sum is divided by the second sum which results in the weighted average. Finally, this number is multiplied with 10 to project it on our scale of 0 to 10. To get the final axis score, the results of the mandatory and conditional mandatory tests are multiplied.

2.1.3 Test Case Weights

The weight of a test case has been defined in regard to achieving a progressive curve: Basic tests get a lower weight so that by passing only basic tests, only a score lower than the average of the weights of all test cases can be achieved, whereas complex tests and tests relevant for security or performance get a higher weight. This relation only applies to tests within the same test axis. Hence, the weight of tests from different axes should not be compared.

The test case weights are listed in the tables of Section 4.

2.2 5GASP's 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 Applications 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 [6], illustrating an end-to-end 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 Section 2 of D2.1 [7] 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. The detailed description is already provided in Section 2 of D5.4 [1].

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 and 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** fulfill the 5G Readiness and the Security & Privacy testing scopes.

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 5G System components during the operation of the Network Application. Since the NEF can be seen as a gateway of the 5G system, if a Network Application can interact with NEF, we assume it can also interact with the 5G Network.

3.1.2 Security & Privacy Testing Axis

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

An additional (optional) set of security tests, applicable to containerized network applications, ensures robust security checks for container images, Kubernetes configurations, and Helm chart installations. Powered by a software security vulnerability scanning tool, designed by 5GASP and specifically for 5G CNFs, it has been seamlessly integrated with the 5GASP CI/CD pipeline.

The 5GASP security scanning tool has an ability to identify security issues in network application software components, with a proficiency in detecting operating system package and software dependencies, sourcing known vulnerabilities from common vulnerability and exposure (CVE) databases, and scanning applications in multiple languages (e.g., Java, Python, C++, RUST). The tool can scan related open-source libraries used within the network application CNF code base, can scan for Infrastructure as Code issues and misconfigurations, and scan for the exposure of sensitive information and secrets within the CNF.

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 End-to-End (E2E) scenario.

3.1.4 Availability & Continuity Testing Axis

The availability and continuity axis evaluates 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 5G System (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 [2] 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 5G System. 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 developers 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.

4 Network Applications Certification Test Cases

This section enumerates all certification-related test cases. Regarding certification, only pre-defined tests are considered, to have a common base for evaluating different network applications. Moreover, the certification-related test cases are split across 4 different testing axis: (i) 5G Readiness, (ii) Security and Privacy, (iii) Performance and Scalability, and (iv) Availability and Continuity. In the following subsections, we further elaborate on all test cases employed during the Network Applications certification process.

4.1 5G Readiness Axis Test Cases

This subsection contains the defined 5G readiness axis test cases along with their unique identification and description. Table 2 - 5G Readiness Axis Test CasesTable 2 enumerates all test cases defined for the 5G Readiness testing axis.

Definition ID	Test Case ID	Test Case	Test Description	Weight
11	def11.5G.1	Authentication with 5GS	This test will validate the authentication and authorization of a Network Application to use 5GS resources (NEF)	3
11	def11.5G.2	Acquisition of UE location	This test will validate that a Network Application is able to retrieve an indicative UE location	5
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)	5
11	def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	This test will validate that a Network Application is able to retrieve indicative information about RSRP	5

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)	5
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)	7
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	7

Table 2 - 5G Readiness Axis Test Cases

Most of the tests in this section require connection to the 5G core through the testing and validation of the applications' connectivity, interfacing options and feedback needs, achieved through the Network Exposure Function (NEF) of the 5G System (5GS) Core. Furthermore, all of them are performed via the 5GASP CI/CD pipeline.

The main test that enables any kind of connection through the NEF to the 5GS core is the NEF Authentication test (def11.5G.1). This test validates if a Network Application can authenticate with the NEF. Authentication is the initial step to interact with this 5G System component. Only after achieving a successful authentication will the Network Application be able to consume data from the 5G Network and invoke specific operations on the 5G System.

To start with, the NEF is made to acquire specific network metric information about certain User Equipment (UEs) within a gNB's coverage area. With that in mind, the Acquisition of UE location test (def11.5G.2) serves to ensure that a Network Application can subscribe to location-related events. Given that 5GASP entails several Automotive Vertical Network Applications, validating that these Applications can consume and subscribe to location data is of utmost importance.

The Acquisition of UE handover event test (def11.5G.3) ensures that a Network Application is equipped with mechanism that enable it to capture handover events. Being aware of such events is crucial for several 5GASP Network Applications.

As above, considering the handover mechanics, the next logical test would be for the Acquisition of UE Received Signal Power (RSRP) information (def11.5G.4), which validates that a Network Application can obtain the RSRP for a given UE. If a Network Application can obtain the RSRP values, it will be capable of adapting its characteristics to the QoS being experienced

by users. For instance, a video streaming network application, by obtaining and analyzing the RSRP information, can adapt its streaming frame rate.

The Acquisition of UE Path loss test (def11.5G.5) ensures that a Network Application can successfully obtain the path losses for a given UE. Obtaining such information is useful for the Network Application to identify coverage gaps and predict signal strength distribution. Therefore, the Network Application can adapt its behavior to cope with these (possible) restrictions.

One of the tests more relevant to certain applications, that need hardware information, the Acquisition of serving cell information test (def11.5G.6) aims at validating that a Network Application can query the cell that is serving a given UE. If the application is capable of getting this information, it will make it possible to invoke specific operations on the 5G Network that target a cell serving one or several Network application clients.

Finally, the Acquisition of QoS sustainability test (def11.5G.7) is used to test if a Network Application can subscribe to QoS Monitoring Information. By doing so, the Network Application is aware of the 5G Network status, for instance, the available bandwidth, latency, packet drops, among other. Based on this information, the Network Application can then invoke operations on the 5G System to cope with QoS downgrades.

4.2 Security & Privacy Axis Test Cases (ITAv, VMware, UNIVBRIS)

To determine the security and privacy levels of a Network Application a set of test cases have been implemented and run through during the on-boarding, deployment phase in the NODS and then via 5GASP CI/CD pipeline run. Table 3 provides an overview of the security and privacy test cases implemented.

Definition ID	Test Case ID	Test Case	Test Description	Weight
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	4
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	4

19	def19.Sec.3	Openstack Port Security	Validate if the Network Application's VNFs have the Port Security enabled, when deployed in Openstack	5
19	def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs	Validate if the Network Application's VNFs offered APIs are protected with SSL	4
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	4
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))	6
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)	8
19	def19.Sec.9	NEF Authentication	Validate if the Network Application is able to authenticate with the NEF before making any requests	6

Table 3 - Security & Privacy Axis Test Cases

The first two test cases, the Package Integrity check (def19.Sec.1) and VNF security-group setting (def19.Sec.2) are executed during the 5GASP NODS on-boarding and deploy phase to help avoiding the on-boarding of unauthorized or modified copies of the given Network Application.

The following set of security test cases are run via the 5GASP CI/CD pipeline.

The Openstack Port Security test (def19.Sec.3) serves to ensure all VNFs deployed in Openstack have port security enabled. If a VNF's interfaces don't have port security enabled, all incoming traffic will be allowed. Thus, the VNF is fully exposed to attacks. With port security enabled, the developer may manage which traffic should be allowed to enter the VNF.

The Secure Sockets Layer (SSL) Protected APIs (def19.Sec.4) test case performs a security assessment of the SSL certificate protecting a resource/endpoint. This test evaluates the certificate's chain, its validity, its cipher suites, etc. The results are then compared against the recommended SSL configuration.

The Secure Shell Protocol (SSH) credentials (def19.Sec.5) test case ensures all SSH credentials used in VNFs are not in the collection of the most common credentials for VMs and that the credentials cannot be easily discovered.

The Open Ports (def19.Sec.7) test case is implemented to identify and evaluate open ports in a Network Application (VM). For this, it uses the Nmap network scanner tool. The primary goal is to ensure the security and integrity of the network by detecting open ports that could potentially be vulnerabilities or entry points for unauthorized access. By systematically scanning and analyzing the network's open ports, this suite plays a critical role in maintaining robust network security. It helps in confirming that only necessary and secure ports are open, and all others are properly closed or shielded, thereby reducing the risk of external attacks and safeguarding sensitive data and service.

The SSH Server Security (def19.Sec.8) test case performs a security assessment of SSH servers in VNFs. It checks the configuration of the SSH server and provides a report of potential security issues and vulnerabilities.

The NEF Authentication (def19.Sec.9) test case is implemented to evaluate the authentication processes of the Network Exposure Function (NEF). Its primary aim is to ensure the NEF's authentication mechanisms are not only robust and secure but also effectively manage and control access to network capabilities and services. The suite tests various authentication scenarios to guarantee that NEF adheres to our strict security protocols and standards, thus maintaining the integrity and reliability of network interactions.

4.2.1 Conditional Mandatory Security & Privacy Axis Test Cases

A set of optional security and privacy test cases have also been implemented and can be run against a Network Application in the 5GASP CI/CD pipeline.

Definition ID	Test Case ID	Test Case	Test Description	Weight
19	def19.Sec.10	Vulnerability Security Report	Validate that network application container image layers are tested for Vulnerabilities, and CIS Benchmark deficiencies.	10
19	def19.Sec.11	SBOM Security Report	Validate that as network applications Software Bill of Materials (SBoM) can be remediated for security vulnerabilities	10

Table 4 - Optional Security & Privacy Axis Test Cases

In 5GASP the security vulnerability scanning tool for def19.Sec.10, hosts a set of tests that leverage a CVE database to specifically identify “Critical CVE” security vulnerabilities within network application CNF images.

Common Vulnerability and Exposure (CVE) databases play a crucial role in today's cybersecurity landscape. The CVE database concept has emerged as a response to the increasing complexity of software and the growing number of security vulnerabilities. The need for a standardized method to identify and share information about vulnerabilities across diverse systems led to the creation of the CVE system.

Several CVE databases have become prominent for example the National Vulnerability Database (NVD), maintained by the US National Institute of Standards and Technology (NIST), is a comprehensive resource providing vulnerability data and severity scores.

The 5GASP security scanner uses different approaches to carry out the vulnerability scan, it will either retrieve a vulnerability report from a Harbor or Docker container repository via API calls, run a local version of the security scanning tool against the CNF image and produce a local vulnerability report, or conduct a vulnerability scan against a SPDX-formatted software bill of materials (SBOM) file of the CNF image.

In relation to the SBOM Security Report (def19.Sec.11) a SBOM file is like a table of contents representation of the CNF and this type of vulnerability scan is an interesting one for network application developers who do not wish to expose the full code base of their CNF, but still require a security vulnerability report.

The 5GASP security scanner is integrated within the CI/CD pipeline of the 5GASP certification process and runs automatically across the network application CNF. The scanner is designed to fail a test if any “critical” security vulnerabilities are found. Critical here means as defined by the CVE standards program. A detailed report identifying the root cause of the critical vulnerability and a possible solution is provided back to the network application developer.

Once a new version of the network application CNF image is pushed to the container repository by the developer, the 5GASP security scanner automatically scans it for vulnerabilities ensuring the most up-to-date CVE database is utilized.

The 5GASP security scanner is set to pass even if high security vulnerabilities are detected, detailed mitigation notes are provided in the report to the developer. In all other cases the scan will pass, including scenarios with medium or low vulnerabilities detected which are reported but not considered fail criteria.

4.3 Performance & Scalability Axis Test Cases

The Performance and Scalability tests evaluate the ability of a Network Application to maintain performance and resource scaling according to the desirable KPIs.

Table 5 lists all the test cases that were defined for this testing axis.

Definition ID	Test Case ID	Test Case	Test Description	Weight
14	def14.Perf.1	E2E download/upload Inter net 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.	8
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.	8

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 signaling performance - response time	Validate by measuring the response time of the Application's endpoint that shall receive notifications from the NEF.	5
14	def14.Perf.6	NEF signaling performance - requests per second	Validate by measuring how many requests per second can the Application's endpoint that shall receive notifications from the NEF support.	5
14	def14.Perf.7	NEF signaling performance - maximum number of connections	Validate by measuring maximum number of simultaneous connections that can be established with the Application's endpoint that shall receive notifications from the NEF.	5

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.	5
14	def14.Perf.9	Network Application - API performance - response time	Validate by measuring Network Application API response time.	5
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.	5
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.	5
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.	8
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.	5

Table 5 - Performance & Scalability Axis Test Cases

All these test cases are performed through the 5GASP CI/CD Pipeline. Moreover, the def14.Perf.1 and def14.Perf.2 tests require two MiniAPIs deployed either (i) on two Network Application components or (ii) one MiniAPI deployed on the Network Application and the other deployed independently on the 5G RAN side to mimic a UE.

The first two tests, “E2E download/upload IP throughput & latency performance, single UE” and “E2E download/upload IP throughput & latency performance, multiple UE,” evaluate the characteristics of the communication channel between the Network Application and a UE (throughput or RTT). However, these tests can also be used to validate the communication

between two Network Application components. For this, the Network Application developers must offer 2 MiniAPIs in their Network Application.

Tests def14.Perf.3 and def14.Perf.4 are used to validate if a Network Application can gather RAN monitoring data. By obtaining this information, a Network Application may adapt its behaviour to cope with the current network status, ensuring a continuous operation and service offering to its clients.

The NEF signaling performance tests (def14.Perf.5, def14.Perf.6, and def14.Perf.7) validate the performance of the Network Application APIs that shall receive notifications from the NEF, either location-related notifications or QoS-related ones. By attesting the performance of those APIs, one can attest that the Network Application can be aware of location and QoS events and cope with them.

The Network Application Web and API performance tests (def14.Perf.8, def14.Perf.9, def14.Perf.10, and def14.Perf.11) ensure the performance of the APIs and static Web Pages offered by the Network Application. These tests can be used to validate how many requests per second can these APIs cope with along with the validation of these APIs/Web Pages response times. Therefore, they are crucial to attest that the Network Application can sustain the desirable performance.

Lastly, the Network Application – IP RTT, and Network Application - IP Traceroute tests ensure that the RTT and the number of hops between the Network Application and a given target are the ones desirable. These tests can be relied upon to evaluate the placement of the different Network Application components. Therefore, after performing these tests, the Network Application owners can adapt the deployment of their applications, tailoring the deployment scenario to minimize the RTT and the number of hops between the different Network Application components.

4.4 Availability & Continuity Axis Test Cases (ITAv, UoP, VMware)

The Availability and Continuity tests evaluate the ability of a Network Application to sustain service over time regarding the provided KPIs, under different stress scenarios like transmission impairments.

To generate such impairments, we rely on Linux Traffic Control (TC). Therefore, these tests are bound to the University of Patras testbed, as this is the only testbed that currently supports Linux TC.

Table 6 lists all the test cases that were defined for this testing axis.

Definition ID	Test Case ID	Test Case	Test Description	Weight
12	def12.Avail Cont.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.	5
12	def12.Avail Cont.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.	5
12	def12.Avail Cont.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.	5
12	def12.Avail Cont.4	Network Application continues its proper functioning after an introduced	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-	5

		packet corruption scenario	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.Avail Cont.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

Table 6 - Availability & Continuity Axis Test Cases

All these test cases can only be performed if a Network Application is deployed in a distributed approach. Some components can reside in Infrastructure A while other reside in Infrastructure B. Due to this, they are only available in the University of Patras testbed, which provides two Kubernetes clusters where Network Application components can be deployed. In order to validate the continuous operation of the Network Applications we rely on Linux Traffic Control (TC) subsystem. TC is used to generate network impairments between the two Kubernetes clusters where the Network Application components reside. After these impairments are created, the test cases validate if the Network Application can sustain its operation, even with under poor network conditions.

The different test cases in the Availability and Continuity test axis are used to generate different network impairments: (i) restricted bandwidth, (ii) introduce packet delay, (iii) packet corruption, (iv) packet loss, and (iv) total disruption of the communication. Therefore, Network Application developers can rely on these tests to better prepare their Network Applications to sustain their operation in a sub-optimal networking scenario.

4.4.1 Conditional Mandatory Availability & Continuity Axis Test Cases

A set of optional availability and continuity test cases have also been implemented and can be run against a Network Application in the 5GASP CI/CD pipeline. These tests are listed below, in Table 7.

Definition ID	Test Case ID	Test Case	Test Description	Weight
12	def12.AvailCont.6	Verify the readiness of Network Application CNFs on Startup	This test uses the Kubernetes API to check the readiness of a Network Application pod or set of pods in a Kubernetes namespace.	7
12	def12.AvailCont.7	Verify the readiness of Network Application CNFs on Restart	This test uses the Kubernetes API to check the readiness of a Network Application pod or set of pods in a Kubernetes namespace after the Network Application service has been restarted.	7

Table 7 - Conditional mandatory Availability & Continuity Axis Test Cases

These two additional tests are only applicable to Network Applications that are offered through CNFs, since they rely on Kubernetes. Regarding their implementation, both tests are very alike, with sole difference that the first (def12.AvailCont.6) validates the readiness of the Network Application pods when the application is started and the second (def12.AvailCont.7) when the application is restarted. To evaluate if the pods are ready, this test relies on Kubernetes API.

Both tests can be relied upon by developers to optimize the deployment time of their Network Applications, as well as their restart time.

5 Status of the 5GASP Certification Process

5.1 Certification Test Cases Implementation

The test cases used for certification have already been addressed in Section 4. This section now details how those tests were implemented, their dependencies, and the components required to execute them.

Regarding the implementation of the test cases, it was achieved by relying on the Robot Framework. As such, all test cases encompass a `.robot` file and a Python file with the main test business logic. Moreover, all test cases also comprise a markdown documentation file, which describes the goal of each test, its inputs, and the expected outcomes. Given the complexity of the tests, we will not delve into further details on their implementation. The test cases are available at https://github.com/5gasp/CICD_LTR/tree/master/ftp/tests, where bash scripts to execute them locally are also available. This allows Network Application owners to test their Network Applications locally, before pushing them to the 5GASP CI/CD Pipeline.

We now move on to the components and dependencies that are required to perform the certification test cases successfully.

Previously, in D5.4 [1], we already introduced the Network Application MiniAPI (<https://github.com/5gasp/NetworkAppControl-MiniAPI>). This so called MiniAPI is used to trigger specific operations on the Network Application, which allows the 5GASP CI/CD Pipeline to control the lifecycle of an application through such an API. Therefore, the MiniAPI is highly relevant for the execution of the 5GASP Tests as it allows to isolate specific operations and validate them in an independent way. Thus, the MiniAPI is a crucial component during the testing and certification of Network Applications. A component that all Network Application must integrate.

The integration of the MiniAPI with the Network Application requires a Network Application to first pass through the 5GASP's Certification process. When the MiniAPI is integrated with a Network Application, the CI/CD Agent will be able to perform a vast collection of test cases: (i) all 5G Readiness tests, (ii) all Security and Privacy tests, (iii) all Availability and Continuity tests, and (iv) some of the Performance and Scalability tests.

However, to perform all test cases, two instances of the MiniAPI are required. While the first one must be packaged inside the Network Application, the second one can be deployed locally on a 5GASP testbed. The second MiniAPI instance aims to mimic a UE, and as such, should be deployed on one. By having two MiniAPIs, one in the Network Application and the other on the UE side, we can more thoroughly validate the interaction between the clients (on UEs) and the Network Application. This enables the execution of performance tests, that evaluate, for instance, how many requests per second can the Network Application serve, the response time of the Network Application, etc.

In regard to dependencies, the MiniAPI requires that the following packages are installed on their host: *iperf3*, *iproute2*, *iputils-ping*, *net-tools*, and *nmap*.

Another component that is required for the testing and certification of Network Applications is a running instance of the NEF Emulator. This component is crucial for the validation of Network Applications, since all 5G Readiness tests rely on validating the interaction between the Network Applications and the NEF. We assume that the NEF is the gateway for interacting with the 5G system and therefore, if a Network Application can successfully interact with the NEF, it can interact with the 5G system. The 5GASP's NEF Emulator is publicly available at <https://github.com/5gasp/NEF-Emulator/>. Moreover, this git repository also comprises a set of instructions on how to deploy and interact with the NEF.

Below, we present all implemented test cases as well as their dependencies.

Definitions	Test Case	Test Description	Relies on the MiniAPI/Similar API?
def11.5G.1	Authentication with 5GS	This test will validate the authentication and authorization of a Network Application to use 5GS resources (NEF)	Yes 1 MiniAPI (Network Application)
def11.5G.2	Acquisition of UE location	This test will validate that a Network Application is able to retrieve an indicative UE location	Yes 1 MiniAPI (Network Application)
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)	Yes 1 MiniAPI (Network Application)
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	This test will validate that a Network Application is able to retrieve indicative information about RSRP	Yes 1 MiniAPI (Network Application)
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)	Yes 1 MiniAPI (Network Application)

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)	Yes 1 MiniAPI (Network Application)
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	Yes 1 MiniAPI (Network Application)
def19.Sec.1	Network Application Package Integrity	Validate package signature, to avoid the onboarding of unauthorized or modified copies of the given Network Application	No
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	No
def19.Sec.3	Openstack Port Security	Validate if the Network Application's VNFs have the Port Security enabled, when deployed in Openstack	No
def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs	Validate if the Network Application's VNFs offered APIs are protected with SSL	No
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	No
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))	No
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)	No
def19.Sec.9	NEF Authentication	Validate if a Network Application is able to authenticate with the NEF before making any requests	Yes 1 MiniAPI (Network Application)

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.	Yes 2 MiniAPIs (Network Application + UE)
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.	Yes 2 MiniAPIs (Network Application + UE)
def14.Perf. 5	NEF signaling performance - response time	Validate by measuring the response time of the Application's endpoint that shall receive notifications from the NEF.	Yes 1 MiniAPI (Network Application)
def14.Perf. 6	NEF signaling performance - requests per second	Validate by measuring how many requests per second can the Application's endpoint that shall receive notifications from the NEF support.	Yes 1 MiniAPI (Network Application)
def14.Perf. 7	NEF signaling performance - maximum number of connections	Validate by measuring maximum number of simultaneous connections that can be established with the Application's endpoint that shall receive notifications from the NEF.	Yes 1 MiniAPI (Network Application)
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.	No
def14.Perf. 9	Network Application - API performance - response time	Validate by measuring Network Application API response time.	No
def14.Perf. 10	Network Application - API performance - requests per second	Validate by measuring how many requests the Network Application API can serve per second.	Yes 1 MiniAPI (Network Application)
def14.Perf. 11	Network Application - API performance - maximum number of connections	Validate by measuring maximum number of simultaneous connections established to the Network Application.	Yes 1 MiniAPI (Network Application)

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.	Yes 1 MiniAPI (Network Application)
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.	Yes 1 MiniAPI (Network Application)
def12.Avail Cont.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.	Yes 1 MiniAPI (Network Application)
def12.Avail Cont.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.	Yes 1 MiniAPI (Network Application)
def12.Avail Cont.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.	Yes 1 MiniAPI (Network Application)

def12.Avail Cont.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.	Yes 1 MiniAPI (Network Application)
def12.Avail Cont.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.	Yes 1 MiniAPI (Network Application)

Table 8 - Implemented Certification Test Cases

By analyzing table above, one may notice that three of the initially defined test cases have not been implemented: def19.Sec.6, def14.Perf.3, and def14.Perf.4.

Test def19.Sec.6 aimed at validating if all Network Application's VNFs offer its functionalities though protected/encrypted access protocols. Since in the 5GASP project the applications are tested as black boxes, it is very difficult to programmatically discover the services/functionalities offered by each interface, not to mention the discovery of these exposed interfaces. Therefore, and considering that we have already developed several tests that validate if an API is protected by SSL and if a VNF's SSH Server can be exploited, we opted not to implement the def19.Sec.6 tests.

Regarding tests def14.Perf.3 and def14.Perf.4, these have not been implemented due to the fact that the 5GASP Network Applications are not consuming RAN monitoring data. However, we are still validating if the Network Applications can obtain network status information, which is achieved by performing the Acquisition of QoS sustainability test (def11.5G.7).

6 Network Application testing preparations

6.1 Network Application testing results

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

6.1.1 Murcia site

Both pre-defined and developer-defined tests were executed and validated in Murcia's testbed infrastructure. Table 9 shows the pre-defined tests that are available to execute in Murcia. The next table (Table 10) indicates the developer-defined tests that were executed together with the Network Applications that were validated with them.

Definitions	Test Case
def11.5G.1	Authentication with 5GS
def11.5G.2	Acquisition of UE location
def11.5G.3	Acquisition of UE handover event
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information
def11.5G.5	Acquisition of UE Path loss
def11.5G.6	Acquisition of serving cell information
def11.5G.7	Acquisition of QoS sustainability
def19.Sec.1	Network Application Package Integrity
def19.Sec.2	VNFs should use a security-group offered by testbed
def19.Sec.3	Openstack Port Security
def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs
def19.Sec.5	Secure Secure Shell Protocol (SSH) Credentials
def19.Sec.7	Open Ports
def19.Sec.8	SSH Server Security
def19.Sec.9	NEF Authentication
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE
def14.Perf.5	NEF signaling performance - response time
def14.Perf.6	NEF signaling performance - requests per second
def14.Perf.7	NEF signaling performance - maximum number of connections

def14.Perf.8	Network Application - web performance (static page)
def14.Perf.9	Network Application - API performance - response time
def14.Perf.10	Network Application - API performance - requests per second
def14.Perf.11	Network Application - API performance - maximum number of connections
def14.Perf.12	Network Application - IP Round-trip time (RTT)
def14.Perf.13	Network Application - IP Traceroute

Table 9 - Available pre-defined tests in Murcia's Testbed

Network Application	Developer-Defined Test Case	Test Case Description
Network Application 1 (click here to access the tests implementation)	API Request Test	Simple HTTP request to validate the functioning of the service
	HTTP Burst Test	HTTP burst request to validate the functioning of the service after a burst of requests
	Database Ready Test	Accesses the databases of the service to check their status and also the one of the different levels of data cache
	Package Check Test	Validates if all the packages required for the service operation are available
Network Application 4 (click here to access the tests implementation)	API Request Test	Simple HTTP request to validate the functioning of the service
	HTTP Burst Test	HTTP burst request to validate the functioning of the service after a burst of requests
	Database Ready Test	Accesses the databases of the service to check their status and also the one of the different levels of data cache
	Package Check Test	Validates if all the packages required for the service operation are available

Table 10 - Developer-defined tests performed in Murcia's Testbed

6.1.2 Aveiro site

In ITAv's testbed, both pre-defined tests and developer-defined tests were performed. In Table 11, we showcase the available pre-defined tests in ITAv. On the other hand, in Table 12, we present the developer-defined tests that were performed, matching them with the respective Network Applications. Finally, in Table 13, we enumerate all Network Applications that were validated and certified in ITAv's Testbed.

The validation and certification results can be seen in Section 7, where we showcase the certificate was awarded through the different Network Applications. The certificate,

besides comprising and overall certification grade, also entails the various test cases that were performed for a Network Application as well as their results.

Furthermore, in order to enable the certification of Network Applications in ITAv's testbed, two components were deployed on their premises. The first is the NEF-Emulator, required to perform tests def11.5G.1 to def11.5G.7. The second, was a MiniAPI instance that was deployed at the same network as the 5G UEs. This MiniAPI allows to mimic the behavior and network capabilities of a 5G UE.

Definitions	Test Case
def11.5G.1	Authentication with 5GS
def11.5G.2	Acquisition of UE location
def11.5G.3	Acquisition of UE handover event
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information
def11.5G.5	Acquisition of UE Path loss
def11.5G.6	Acquisition of serving cell information
def11.5G.7	Acquisition of QoS sustainability
def19.Sec.1	Network Application Package Integrity
def19.Sec.2	VNFs should use a security-group offered by testbed
def19.Sec.3	Openstack Port Security
def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs
def19.Sec.5	Secure Secure Shell Protocol (SSH) Credentials
def19.Sec.7	Open Ports
def19.Sec.8	SSH Server Security
def19.Sec.9	NEF Authentication
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE
def14.Perf.5	NEF signaling performance - response time
def14.Perf.6	NEF signaling performance - requests per second
def14.Perf.7	NEF signaling performance - maximum number of connections
def14.Perf.8	Network Application - web performance (static page)
def14.Perf.9	Network Application - API performance - response time
def14.Perf.10	Network Application - API performance - requests per second
def14.Perf.11	Network Application - API performance - maximum number of connections
def14.Perf.12	Network Application - IP Round-trip time (RTT)
def14.Perf.13	Network Application - IP Traceroute

Table 11 - Available pre-defined tests in ITAv's Testbed

Network Application	Developer-Defined Test Case	Test Case Description
Network Application 1 (click here to access the tests implementation)	API Request Test	Simple HTTP request to validate the functioning of the service
	HTTP Burst Test	HTTP burst request to validate the functioning of the service after a burst of requests
	Database Ready Test	Accesses the databases of the service to check their status and also the one of the different levels of data cache
	Package Check Test	Validates if all the packages required for the service operation are available
Network Application 4 (click here to access the tests implementation)	API Request Test	Simple HTTP request to validate the functioning of the service
	HTTP Burst Test	HTTP burst request to validate the functioning of the service after a burst of requests
	Database Ready Test	Accesses the databases of the service to check their status and also the one of the different levels of data cache
	Package Check Test	Validates if all the packages required for the service operation are available
Network Application 8 (click here to access the tests implementation)	API Server Connectivity Test	Evaluates if the flaskweb API server is reachable both in and out the K8s cluster where PrivacyAnalyzer is deployed.
	DB Server Readiness Test	Evaluates if the Network Application's mongoDB database: (i) is up and running and (ii) is properly configured (e.g. initial collections are created, authorization is successful, etc.)
	E2E Readiness and Production of Correct Privacy Analysis Test	In this test, some predefined messages are sent from a producer container and analyzed by the next in chain containers (format-detector, encrypt-detector, pattern-detector, anonym-detector). The results of the analysis are saved in the mongoDB container. The test checks if the results are properly saved in the database (in the correct collections, with the correct formats) and of course, if the results are the expected ones based on the input messages.

Table 12 - Developer-defined tests performed in ITAv's Testbed

Network Applications Tested and Certified in ITAv's Testbed
Network Application 1: Virtual On-Board Unit Provisioning Network Application (VOBU)
Network Application 2: Virtual Roadside Unit Provisioning Network Application (VRSU)
Network Application 3: C-ITS Station Network Application
Network Application 4: Multi-Domain Migration Network Application
Network Application 8: Privacy Analyzer Network Application

Table 13 - Network Applications Tested and Certified in ITAv's Testbed

6.1.3 Bristol site

In the 5GUK testbed, both pre-defined tests and developer-defined tests were performed, in CNF format. In Table 14, we showcase the available pre-defined tests in the UNIVBRIS testbed. Further, as our app is heavily dependent on the 5G network, the majority of our developer-defined tests were also used in the definition of the pre-defined 5G tests, also available in Table 14, presented as def11.5G.1-5, were performed on our own network application (NApp 7: EMHO) and testbed.

The validation and certification results for our NApp can be seen in Sub-Section 7, where we showcase the certificate Network Applications. The certificate, besides comprising and overall certification grade, also entails the various test cases that were performed for a Network Application as well as their results.

Furthermore, in order to enable the certification of Network Applications on the UNIVBRIS testbed, two components were deployed on premises. The first is the NEF-Emulator, required to perform tests def11.5G.1 to def11.5G.7, and def19.Sec.9. The second, was a MiniAPI instance, together with a Kubernetes adaptation, through the development of a full deployment helm chart, exposing network interfaces, for the purpose of implementing the necessary test infrastructure. This MiniAPI allows to mimic the behavior and network capabilities of a 5G-compliant and compatible UE.

Definitions	Test Case
def11.5G.1	Authentication with 5GS
def11.5G.2	Acquisition of UE location
def11.5G.3	Acquisition of UE handover event
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information
def11.5G.5	Acquisition of UE Path loss
def11.5G.6	Acquisition of serving cell information
def11.5G.7	Acquisition of QoS sustainability
def19.Sec.1	Network Application Package Integrity
def19.Sec.2	VNFs should use a security-group offered by testbed
def19.Sec.3	Openstack Port Security

def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs
def19.Sec.5	Secure Secure Shell Protocol (SSH) Credentials
def19.Sec.7	Open Ports
def19.Sec.8	SSH Server Security
def19.Sec.9	NEF Authentication
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE
def14.Perf.5	NEF signaling performance - response time
def14.Perf.6	NEF signaling performance - requests per second
def14.Perf.7	NEF signaling performance - maximum number of connections
def14.Perf.8	Network Application - web performance (static page)
def14.Perf.9	Network Application - API performance - response time
def14.Perf.10	Network Application - API performance - requests per second
def14.Perf.11	Network Application - API performance - maximum number of connections
def14.Perf.12	Network Application - IP Round-trip time (RTT)
def14.Perf.13	Network Application - IP Traceroute

Table 14 - Available pre-defined tests in 5G UK Testbed

6.1.4 Patras site

UoP's testbed offers several pre-defined tests. Moreover, this testbed also supports the execution of developer-defined tests. In Table 15, we present the available pre-defined tests in UoP. On the other hand, in Table 16, we present the developer-defined tests that were performed, matching them with the respective Network Applications. Finally, in Table 17, we enumerate all Network Applications that were validated and certified in this testbed.

The validation and certification results obtained in this testbed can be seen in Section 7, where we showcase the certificate the was awarded through the different Network Applications.

Additionally, to enable the certification of Network Applications in UoP's testbed, two components were deployed on its premises. The first is the NEF-Emulator, required to perform tests def11.5G.1 to def11.5G.7. The second, was a MiniAPI instance that was deployed at the same network as the 5G UEs. This MiniAPI allows to mimic the behavior and network capabilities of a 5G UE.

Definitions	Test Case
def11.5G.1	Authentication with 5GS
def11.5G.2	Acquisition of UE location
def11.5G.3	Acquisition of UE handover event
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information
def11.5G.5	Acquisition of UE Path loss
def11.5G.6	Acquisition of serving cell information
def11.5G.7	Acquisition of QoS sustainability
def19.Sec.1	Network Application Package Integrity
def19.Sec.2	VNFs should use a security-group offered by testbed
def19.Sec.3	Openstack Port Security
def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs
def19.Sec.5	Secure Secure Shell Protocol (SSH) Credentials
def19.Sec.7	Open Ports
def19.Sec.8	SSH Server Security
def19.Sec.9	NEF Authentication
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE
def14.Perf.5	NEF signaling performance - response time
def14.Perf.6	NEF signaling performance - requests per second
def14.Perf.7	NEF signaling performance - maximum number of connections
def14.Perf.8	Network Application - web performance (static page)
def14.Perf.9	Network Application - API performance - response time
def14.Perf.10	Network Application - API performance - requests per second
def14.Perf.11	Network Application - API performance - maximum number of connections
def14.Perf.12	Network Application - IP Round-trip time (RTT)
def14.Perf.13	Network Application - IP Traceroute
def12.AvailCont.1	Network Application continues its proper functioning after restricted bandwidth scenario
def12.AvailCont.2	Network Application continues its proper functioning after an introduced delay scenario
def12.AvailCont.3	Network Application continues its proper functioning after an introduced packet loss scenario
def12.AvailCont.4	Network Application continues its proper functioning after an introduced packet corruption scenario
def12.AvailCont.5	Network Application continues its proper functioning after an introduced total disruption of communication scenario

Table 15 - Available pre-defined tests in UoP's Testbed

Network Application	Developer-Defined Test Case	Test Case Description
Network Application 10 (click here to access the tests implementation)	Main API Test	This test validates that VRO's main API is available
	Neobility Routing Engine Test	Validates if the Routing Engine component is behaving as expected
	Neobility Transport API Test	This test validates that VRO's Transport API is available
	OSMR Test	Validates if the OSMR component is behaving as expected
Network Application 11 (click here to access the tests implementation)	Web UI readiness Test	Validates that all the Network Application's components are active, therefore the application's UI is accessible
	HTTP burst Test	Validates that the Network Application can maintain its proper functionality after a series of burst requests are performed towards its UI and API
	Fire Detection Test	Confirms the Network Application's capability to detect fire, by examining designated frames on a provided sample video stream file

Table 16 - Developer-defined tests performed in UoP's Testbed

Network Applications Tested and Certified in UoP's Testbed
Network Application 7: Efficient MEC Handover Network Application
Network Application 10: Vehicle Route Optimizer Network Application
Network Application 11: Fire Detection and Ground Assistance using Drones (FIDEGAD)

Table 17 - Network Applications Tested and Certified in UoP's Testbed

6.1.5 Bucharest site

ORO's testbed hosted both pre-defined and developer-defined test. Table 18 lists the pre-defined tests available for selection while Table 19 lists the developer-defined tests performed.

Definitions	Test Case
def11.5G.1	Authentication with 5GS
def11.5G.2	Acquisition of UE location
def11.5G.3	Acquisition of UE handover event
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information
def11.5G.5	Acquisition of UE Path loss
def11.5G.6	Acquisition of serving cell information

def11.5G.7	Acquisition of QoS sustainability
def19.Sec.1	Network Application Package Integrity
def19.Sec.2	VNFs should use a security-group offered by testbed
def19.Sec.3	Openstack Port Security
def19.Sec.4	Secure Sockets Layer (SSL) Protected APIs
def19.Sec.5	Secure Secure Shell Protocol (SSH) Credentials
def19.Sec.7	Open Ports
def19.Sec.8	SSH Server Security
def19.Sec.9	NEF Authentication
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE
def14.Perf.5	NEF signaling performance - response time
def14.Perf.6	NEF signaling performance - requests per second
def14.Perf.7	NEF signaling performance - maximum number of connections
def14.Perf.8	Network Application - web performance (static page)
def14.Perf.9	Network Application - API performance - response time
def14.Perf.10	Network Application - API performance - requests per second
def14.Perf.11	Network Application - API performance - maximum number of connections
def14.Perf.12	Network Application - IP Round-trip time (RTT)
def14.Perf.13	Network Application - IP Traceroute
def12.AvailCont.1	Network Application continues its proper functioning after restricted bandwidth scenario
def12.AvailCont.2	Network Application continues its proper functioning after an introduced delay scenario
def12.AvailCont.3	Network Application continues its proper functioning after an introduced packet loss scenario
def12.AvailCont.4	Network Application continues its proper functioning after an introduced packet corruption scenario
def12.AvailCont.5	Network Application continues its proper functioning after an introduced total disruption of communication scenario

Table 18 - Available Pre-defined tests in ORO's testbed

Network Application	Developer-Defined Test Case	Test Case Description
Network Application 10 (click here to access the tests implementation)	Main API Test	This test validates that VRO's main API is available
	Neobility Routing Engine Test	Validates if the Routing Engine component is behaving as expected
	Neobility Transport API Test	This test validates that VRO's Transport API is available
	OSMR Test	Validates if the OSMR component is behaving as expected

Table 19 - Developer-Defined tests performed in ORO's testbed

6.1.6 Ljubljana Site

In ININ's testbed, both pre-defined tests and developer-defined tests were performed. In Table 20, we showcase the available pre-defined tests in ININ. On the other hand, in Table 21, we present the developer-defined tests that were performed, matching them with the respective Network Applications. Finally, in Table 22, we enumerate all Network Applications that were validated and certified in ININ's Testbed.

The validation and certification results can be seen in Section 7, where we showcase the certificate the was awarded through the different Network Applications. The certificate, besides comprising and overall certification grade, also entails the various test cases that were performed for a Network Application as well as their results.

Definitions	Test Case
def11.5G.1	Authentication with 5GS
def11.5G.3	Acquisition of UE handover event
def11.5G.5	Acquisition of UE Path loss
def11.5G.6	Acquisition of serving cell information
def11.5G.7	Acquisition of QoS sustainability
def19.Sec.1	Network Application Package Integrity
def19.Sec.9	NEF Authentication
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE
def14.Perf.5	NEF signaling performance - response time
def14.Perf.6	NEF signaling performance - requests per second
def14.Perf.7	NEF signaling performance - maximum number of connections
def14.Perf.8	Network Application - web performance (static page)

def14.Perf.9	Network Application - API performance - response time
def14.Perf.10	Network Application - API performance - requests per second
def14.Perf.11	Network Application - API performance - maximum number of connections
def14.Perf.12	Network Application - IP Round-trip time (RTT)
def14.Perf.13	Network Application - IP Traceroute

Table 20 - Available pre-defined tests in ININ's Testbed

Network Application	Developer-Defined Test Case	Test Case Description
Network Application 9 (click here to access the tests implementation)	IOPS Network Application Component Readiness	A batch of tests verifying the operation of Network Application including: <ul style="list-style-type: none"> • gNB component readiness • CN component readiness • 5G UE registration
	IOPS Internet Connectivity Test	A batch of tests verifying that 5G UE connected to IOPS slice provided by the Network Application can access internet services.
	IOPS Local Connectivity Test	A batch of tests verifying that 5G UE connected to IOPS slice provided by the Network Application can access local services, including: <ul style="list-style-type: none"> • PING test • DNS test • WEB test • Packet Loss • IP throughput Download • IP Throughput Upload

Table 21 - Developer-defined tests performed in ININ's Testbed

Network Applications Tested and Certified in ININ's Testbed
Network Application 9: Isolated Operation for Public Safety (IOPS) Network Application

Table 22 - Network Applications Tested and Certified in ININ's Testbed

6.2 Network Application Test Plans

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)

The Virtual On-board Unit Provisioning Network Application followed the recommendations by 5GASP to comply with the certification requirements. All the tests were executed through the 5GASP CICD pipeline in an automated way, following the automation principles in design, development, deployment and validation proposed by 5GASP guidelines and framework. Besides, developer-defined tests were also defined and executed to validate the operation and functioning of the Network Application-specific software once deployed in the 5GASP infrastructure. The final test plan is presented in the table below. The results of the execution of the test plan can be seen in Section 7.

Virtual On-board Unit Provisioning Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification

def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.1	Network Application Package Integrity	pass	CICD - certification
def19.Sec.2	Network Application should use a security-group offered by testbed	pass	CICD - certification
def19.Sec.3	Openstack port security	pass	CICD - certification
def19.Sec.4	SSL audit	pass	CICD - certification
def19.Sec.5	SSH Brute Force	pass	CICD - certification
def19.Sec.7	Open ports	pass	CICD - certification
def19.Sec.8	SSH audit	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification

def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification
Network Application Specific Tests			
API Request Test vOBU	Simple HTTP request to validate the functioning of the service	pass	CICD – developer-defined
API Request Test Manager	Simple HTTP request to validate the functioning of the service	pass	CICD – developer-defined
API Request Test Aggregator	Simple HTTP request to validate the functioning of the service	pass	CICD – developer-defined
HTTP Burst Test	HTTP burst request to validate the functioning of the service after a burst of requests	pass	CICD – developer-defined
Database Ready Test	Accesses the databases of the service to check their status and also the one of the different levels of data cache	pass	CICD – developer-defined
Package Check Test	Validates if all the packages required for the service operation are available	pass	CICD – developer-defined

Table 23 - Virtual On-board Unit Provisioning Network Application Final Test Plan

6.2.2 Network Application 2: Virtual Roadside Unit Provisioning Network Application (VRSU)

The Virtual Roadside Unit Provisioning (VRSU) Network Application adhered to 5GASP's recommendations for certification compliance. All certification-related tests were conducted automatically via the 5GASP CICD Pipeline, according to the automation principles defined in 5GASP. Additionally, to perform all certification-required tests, a Control MiniAPI API was integrated. This API enables the control of the application's lifecycle by the CI/CD Pipeline,

which triggers specific operations on the Network Application through it. Moreover, it was also required to deploy a local instance of NEF-Emulator as the 5G Readiness tests require the interaction between the Network Application and this component. The details of the certification test plan are provided in the table below, where we enumerate all certification-related tests that were performed on this application. Finally, the test execution results available in Section 7.

Virtual Roadside Unit Provisioning (VRSU) Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.1	Network Application Package Integrity	pass	CICD - certification
def19.Sec.2	Network Application should use a security-group offered by testbed	pass	CICD - certification
def19.Sec.3	Openstack port security	pass	CICD - certification
def19.Sec.4	SSL Audit	fail	CICD - certification
def19.Sec.5	SSH Brute Force	pass	CICD - certification
def19.Sec.7	Open Ports	pass	CICD - certification
def19.Sec.8	SSH Audit	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification

def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification

Table 24 -Virtual Roadside Unit Provisioning (VRSU) Network Application Final Test Plan

6.2.3 Network Application 3: C-ITS Station Network Application

The C-ITS Station Network Application adhered to the certification compliance recommendations set forth by 5GASP. All certification tests were automated through the 5GASP CICD Pipeline, following the automation principles outlined by 5GASP. Additionally, integration of a Control MiniAPI API allowed for the execution of certification-required tests, enabling the CI/CD Pipeline to manage the application's lifecycle and trigger specific operations. Furthermore, deployment of a local instance of NEF-Emulator was necessary to

enable interaction between the Network Application and this component for the 5G Readiness tests. The certification test plan details are provided in the table below, enumerating all relevant tests conducted on the application. The results of the test execution are available in Section 7.

Virtual C-ITS Station Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.1	Network Application Package Integrity	pass	CICD - certification
def19.Sec.2	Network Application should use a security-group offered by testbed	pass	CICD - certification
def19.Sec.3	Openstack port security	pass	CICD - certification
def19.Sec.4	SSL Audit	fail	CICD - certification
def19.Sec.5	SSH Brute Force	pass	CICD - certification
def19.Sec.7	Open Ports	pass	CICD - certification
def19.Sec.8	SSH Audit	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification

def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification

Table 25 - Virtual C-ITS Station Network Application Final Test Plan

6.2.4 Network Application 4: Multi-Domain Migration Network Application

The Multi-domain Migration Network Application followed the recommendations by 5GASP to comply with the certification requirements. All the tests were executed through the 5GASP CICD pipeline in an automated way, following the automation principles in design, development, deployment and validation proposed by 5GASP guidelines and framework. Besides, developer-defined tests were also defined and executed to validate the operation and functioning of the Network Application-specific software once deployed in the 5GASP

infrastructure. The final test plan is presented in the table below. The results of the execution of the test plan can be seen in Section 7.

Multi-domain Migration Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.1	Network Application Package Integrity	pass	CICD - certification
def19.Sec.2	Network Application should use a security-group offered by testbed	pass	CICD - certification
def19.Sec.3	Openstack port security	pass	CICD - certification
def19.Sec.4	SSL audit	pass	CICD - certification
def19.Sec.5	SSH Brute Force	pass	CICD - certification
def19.Sec.7	Open ports	pass	CICD - certification
def19.Sec.8	SSH audit	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification

def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification
Network Application Specific Tests			
API Request Test vOBU	Simple HTTP request to validate the functioning of the service	pass	CICD – developer-defined
API Request Test Manager	Simple HTTP request to validate the functioning of the service	pass	CICD – developer-defined
API Request Test Aggregator	Simple HTTP request to validate the functioning of the service	pass	CICD – developer-defined
HTTP Burst Test	HTTP burst request to validate the functioning of the service after a burst of requests	pass	CICD – developer-defined

Database Ready Test	Accesses the databases of the service to check their status and also the one of the different levels of data cache	pass	CICD – developer-defined
Package Check Test	Validates if all the packages required for the service operation are available	pass	CICD – developer-defined

Table 26 - Multi-domain Migration Network Application Final Test Plan

6.2.5 Network Application 5: Vehicle-To-Cloud Real-Time Communication Network Application

In order to prepare the Vehicle-to-Cloud (V2C) Real-Time Communication Network Application for testing and certification within the 5GASP's CI/CD Pipeline, the integration of the Control MiniAPI was essential. This API facilitates the CI/CD Agent in managing the application's lifecycle and in triggering specific operations, which are vital for the certification of Network Applications on the 5GASP platform. Additionally, given that the 5G Readiness tests assess the interaction between the Network Application and the NEF, a local instance of the NEF-Emulator was deployed. To ensure full compatibility with the VNF deployment type, methods for deploying the extra MiniAPI entity (UE) pod and nodePort services were developed, including standard YAML manifests and a comprehensive helm chart tailored for the MiniAPI pod and service deployment. The testing plan for the V2C Network Application was methodically executed both locally and on the 5GASP Platform's CI/CD Pipeline. The test expected results are reflected in the "Expected Results" column.

Vehicle-to-Cloud (V2C) Real-Time Communication Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification

def19.Sec.1	Network Application Package Integrity	pass	CICD - certification
def19.Sec.2	Network Application should use a security-group offered by testbed	pass	CICD - certification
def19.Sec.3	Openstack port security	pass	CICD - certification
def19.Sec.4	SSL Audit	fail	CICD - certification
def19.Sec.5	SSH Brute Force	pass	CICD - certification
def19.Sec.7	Open Ports	pass	CICD - certification
def19.Sec.8	SSH Audit	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	fail	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification

Table 27 - Vehicle-to-Cloud (V2C) Real-Time Communication Network Application Final Test Plan

6.2.6 Network Application 6: Remote Human Driving Network Application - Teleoperation for Assisting Vehicles In Complex Situations

To prepare the Remote Human Driving Network Application - Teleoperation for Assisting Vehicles in Complex Situations for testing and certification on the 5GASP's CI/CD Pipeline, integrating the Control MiniAPI was crucial. This API enables the CI/CD Agent to oversee the application's lifecycle and initiate specific actions essential for certifying Network Applications under 5GASP. Moreover, due to the 5G Readiness tests examining the interaction between the Network Application and the NEF, a local NEF-Emulator instance was installed. Like the V2C application, this application's testing procedure was aligned with the VNF deployment strategy, involving similar deployment methods for the additional MiniAPI entity (UE) pod and nodePort services. The testing plan for this Network Application, consistent with the structured approach used for V2C, continues to be implemented with its outcomes anticipated in the "Expected Results" column of the testing documentation.

"Remote Human Driving Network Application - Teleoperation for Assisting Vehicles in Complex Situation" Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.1	Network Application Package Integrity	pass	CICD - certification
def19.Sec.2	Network Application should use a security-group offered by testbed	pass	CICD - certification
def19.Sec.3	Openstack port security	pass	CICD - certification

def19.Sec.4	SSL Audit	fail	CICD - certification
def19.Sec.5	SSH Brute Force	pass	CICD - certification
def19.Sec.7	Open Ports	pass	CICD - certification
def19.Sec.8	SSH Audit	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	fail	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification

Table 28 - "Remote Human Driving Network Application - Teleoperation for Assisting Vehicles in Complex Situation" Final Test Plan

6.2.7 Network Application 7: Efficient MEC Handover Network Application

In order to prepare the Efficient MEC HandOver (EMHO) network application for being tested and certified in 5GASP's CI/CD Pipeline, the integration of the Control MiniAPI was needed. This API allows for the CI/CD Agent to manage the application's lifecycle and trigger specific operations, crucial to the certification of Network Applications through the 5GASP platform. Moreover, since the 5G Readiness tests evaluate the interaction between the Network Application and the NEF, a local instance of NEF-Emulator was deployed. Furthermore, for the testing procedures to be fully compatible with the CNF type of deployment, we have developed two other methods of deploying the extra MiniAPI entity (UE) pod and nodePort services: normal yaml manifests and a complete helm chart, specifically madae for the MiniAPI pod and service deployment. In the table below, we showcase the testing plan for the EMHO Network Application. All tests in this table were conducted locally, and then in the 5GASP Platform's CI/CD Pipeline.

Efficient MEC Handover Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application certification tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification

def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	fail	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	fail	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	fail	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification
def12.AvailCont.1	Network Application continues its proper functioning after restricted bandwidth scenario	pass	CICD - certification
def12.AvailCont.2	Network Application continues its proper functioning after an introduced delay scenario	pass	CICD - certification
def12.AvailCont.3	Network Application continues its proper functioning after an introduced packet loss scenario	pass	CICD - certification

def12.AvailCont.4	Network Application continues its proper functioning after an introduced packet corruption scenario	pass	CICD - certification
def12.AvailCont.5	Network Application continues its proper functioning after an introduced total disruption of communication scenario	pass	CICD - certification

Table 29 - Efficient MEC Handover Network Application Final Test Plan

6.2.8 Network Application 8: PrivacyAnalyzer Network Application

The PrivacyAnalyzer Network Application followed the recommendations by 5GASP to comply with the certification requirements. All the tests were executed through the 5GASP CICD pipeline in an automated way, following the automation principles in design, development, deployment and validation proposed by 5GASP guidelines and framework. Besides, developer-defined tests were also defined and executed to validate the operation and functioning of the Network Application-specific software once deployed in the 5GASP infrastructure. The final test plan is presented in the table below. The results of the execution of the test plan can be seen in Section 7.

PrivacyAnalyzer Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.1	Network Application Package Integrity	pass	CICD - certification

def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification
Network Application Specific Tests			
API Server Connectivity Test	Evaluates if the flaskweb API server is reachable both in and out the K8s cluster where PrivacyAnalyzer is deployed.	pass	CICD – developer-defined
DB Server Readiness Test	Evaluates if the Network Application's mongoDB database: (i) is up and running and (ii) is properly configured (e.g. initial collections are created, authorization is successful, etc.)	pass	CICD – developer-defined
E2E Readiness And Production of Correct Privacy Analysis Test	In this test, some predefined messages are sent from a producer container and analyzed by the next in chain containers (format-detector, encrypt-detector, pattern-detector, anonym-detector). The results of the analysis are saved in the mongoDB container. The test checks if the results are properly saved in the database (in the correct collections, with the correct formats) and of course, if the results are the expected ones based on the input messages.	pass	CICD – developer-defined

Table 30 - PrivacyAnalyzer Network Application Final Test Plan

To be able to pass both the 5GASP test cases and the developer-defined test cases described earlier, the CNF-based PrivacyAnalyzer Network Application was extended in order that it is ready to enter the 5GASP testing / certification automated pipeline.

To that end, we have added an extra container in our deployment, named ‘networkapp-miniaPI’ as shown in the figure below. This has been implemented following the guidelines provided by the 5GASP project to all Network Application owners, with codebase and documentation available from <https://github.com/5gasp/NetworkAppControl-MiniAPI>.

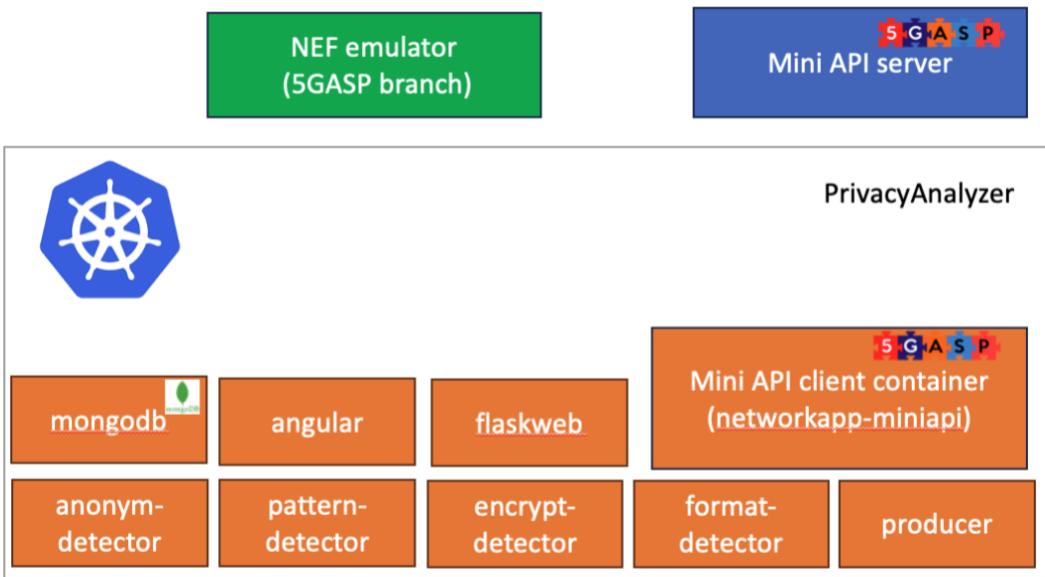


Figure 3 - Addition of 5GASP's Mini API as an extra container in PrivacyAnalyzer deployment

The final local deployment shown in the above figure has been used for successfully passing the 5GASP testing / certification pipeline.

With the above having been achieved during the last phase of the project, PrivacyAnalyzer received its 5GASP Gold Certification.

6.2.9 Network Application 9: 5G Isolated Operation for Public Safety (IOPS) Network Application

The Isolated Operations for Public Safety (IOPS) Network Application followed selected mandatory tests to comply with 5GASP’s Network Application certification requirements. Additionally, IOPS Network Application was tested against selected PPDR vertical tests available at ININ’s testbed, specifically targeting PPDR IOPS operation and UE connectivity over the PPDR IOPS slice. All test cases are fully automated and included in the testing descriptor to be able to run directly on the 5GASP CICD pipeline (exception are the 4 tests for IOPS failure/restore scenario which should be triggered manually due 5G UE reconnecting).

Furthermore, Network Application specific test cases were defined to fully test the basic functionality and operation of the IOPS Network Application and performance of the PPDR slice provided by the Network Application. All Network Application specific tests are fully automated and integrated in CICD pipeline as show in the table below.

Isolated Operations for Public Safety Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.1	Network Application Package Integrity	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification

def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification
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	CICD – developer-defined; manual intervention may be needed to reconnect smart phone
PPDR UE (5G gateway) - network connectivity	This test validates that the 5G UE (gateway) can reach the public services over the PPDR network	pass	CICD – developer-defined
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	ROBOT – developer-defined; manual intervention may be needed to reconnect smart phone
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	ROBOT – developer-defined; manual intervention may be needed to reconnect smart phone
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	ROBOT – developer-defined; manual intervention may be needed to reconnect smart phone

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	ROBOT – developer-defined; manual intervention may be needed to reconnect smart phone
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	CICD – developer-defined; manual intervention may be needed to reconnect smart phone
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	CICD – developer-defined
Network Application Specific Tests			
IOPS gNB Component readiness	Send HTTP request to validate the functionality of the service	pass	CICD – developer-defined
IOPS CN Component readiness	Send HTTP request to validate the functionality of the service	pass	CICD – developer-defined
Web test	Send HTTP request to validate the functionality of the configured service (e.g. google.com)	pass	CICD – developer-defined
DNS test	Send DNS request to validate the functionality of the service	pass	CICD – developer-defined
Ping test	Send sequence of Ping requests to validate E2E connectivity and to measure response time	pass	CICD – developer-defined
IP throughput download test	Download a specific amount of data to estimate download data rate	pass	CICD – developer-defined
IP throughput upload test	Upload a specific amount of data to estimate upload data rate	pass	CICD – developer-defined
Packet loss	Transfer a specific amount of data to estimate packet loss	pass	CICD – developer-defined

Table 31 - Isolated Operations for Public Safety Network Application Final Test Plan

6.2.10 Network Application 10: Vehicle Route Optimizer (VRO) Network Application

Preparing Network Application 10 (Vehicle Route Optimizer) to be tested and certified in 5GASP implied multiple developments. Since the Network Application is a Cloud-native Network Function (CNF) made up of 4 components, a specific component was chosen for specific tests to be run. For example, for the 5G Readiness tests, the component interacting with the NEF Emulator was chosen, more specifically the "Transport API" (also called "Driver API" in D5.4 [1]). As, for the developer defined tests, all components of the Network Application are being tested to verify the APIs are correctly running. All tests were conducted locally and on the 5GASP's CI/CD Pipeline.

VRO Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification

def14.Perf.5	NEF signaling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signaling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signaling performance - maximum number of connections	pass	CICD - certification
def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification
def12.AvailCont.1	Network Application continues its proper functioning after restricted bandwidth scenario	pass	CICD - certification
def12.AvailCont.2	Network Application continues its proper functioning after an introduced delay scenario	pass	CICD - certification
def12.AvailCont.3	Network Application continues its proper functioning after an introduced packet loss scenario	pass	CICD - certification

def12.AvailCont.4	Network Application continues its proper functioning after an introduced packet corruption scenario	pass	CICD - certification
def12.AvailCont.5	Network Application continues its proper functioning after an introduced total disruption of communication scenario	pass	CICD - certification
Network Application Specific Tests			
Main API Test	Validates that the Network Application user side service API is functioning correctly.	pass	CICD – developer-defined
Neo Routing Engine Test	Validates that the Network Application Routing Engine and Routing Engine Estimation services are able to process ride requests.	pass	CICD – developer-defined
Neo Transport API Test	Validates that the Network Application driver side service API is functioning correctly.	pass	CICD – developer-defined
Neo OSRM Test	Validates that the Network Application's OSRM (Open Source Routing Machine) service is able to process driving directions.	pass	CICD – developer-defined

Table 32 - VRO Network Application Final Test Plan

6.2.11 Network Application 11: Fire Detection and Ground Assistance Using Drones (FIDEGAD)

The FIDEGAD Application followed all the designated guidelines and recommendations by 5GASP and successfully complied with the overall imposed test conditions. Specifically, the tests derived and executed based on the applied conditions, i.e. data plane application, container deployment type, location and mobility-based application, NEF support and Premium QoS application, are presented in **Error! Reference source not found.**. All the tests were performed through the automated 5GASP CI/CD pipeline universally adhering to the design, development, deployment and validation principles proposed by 5GASP. Moreover,

several developer-defined tests were introduced and executed to validate the operation and the proper functioning of the Network Application's specific use cases and software. The execution results of the overall test plan can be found in Section 7.

FIDEGAD Network Application Final Test Plan			
Test	Description	Expected Results	Comments
Network Application Certification Tests			
def11.5G.1	Authentication with 5GS	pass	CICD - certification
def11.5G.2	Acquisition of UE location	pass	CICD - certification
def11.5G.3	Acquisition of UE handover event	pass	CICD - certification
def11.5G.4	Acquisition of UE Received Signal Power (RSRP) information	pass	CICD - certification
def11.5G.5	Acquisition of UE Path loss	pass	CICD - certification
def11.5G.6	Acquisition of serving cell information	pass	CICD - certification
def11.5G.7	Acquisition of QoS sustainability	pass	CICD - certification
def19.Sec.9	NEF Authentication	pass	CICD - certification
def14.Perf.1	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	pass	CICD - certification
def14.Perf.2	E2E download/upload IP throughput & latency performance, multiple UE	pass	CICD - certification
def14.Perf.5	NEF signalling performance - response time	pass	CICD - certification
def14.Perf.6	NEF signalling performance - requests per second	pass	CICD - certification
def14.Perf.7	NEF signalling performance - maximum number of connections	pass	CICD - certification

def14.Perf.8	Network Application - web performance (static page)	pass	CICD - certification
def14.Perf.9	Network Application - API performance - response time	pass	CICD - certification
def14.Perf.10	Network Application - API performance - requests per second	pass	CICD - certification
def14.Perf.11	Network Application - API performance - maximum number of connections	pass	CICD - certification
def14.Perf.12	Network Application - IP Round-trip time (RTT)	pass	CICD - certification
def14.Perf.13	Network Application - IP Traceroute	pass	CICD - certification
def12.AvailCont.1	Network Application continues its proper functioning after restricted bandwidth scenario	pass	CICD - certification
def12.AvailCont.2	Network Application continues its proper functioning after an introduced delay scenario	pass	CICD - certification
def12.AvailCont.3	Network Application continues its proper functioning after an introduced packet loss scenario	pass	CICD - certification
def12.AvailCont.4	Network Application continues its proper functioning after an introduced packet corruption scenario	pass	CICD - certification
def12.AvailCont.5	Network Application continues its proper functioning after an introduced total disruption of communication scenario	pass	CICD - certification

Network Application Specific Tests			
Web UI readiness Test	Validates that all the Network Application's components are active, therefore the application's UI is accessible	pass	CICD – developer-defined
HTTP Burst Test	Validates that the Network Application can maintain its proper functionality after a series of burst requests are performed towards its UI and API	pass	CICD – developer-defined
Fire Detection Test	Confirms the Network Application's capability to detect fire, by examining designated frames on a provided sample video stream file	pass	Local execution – developer-defined (the provided video stream file size was exceeding the supported limits of the CI/CD pipeline)

Table 33 - FIDEGAD Network Application Final Test Plan

7 Certification results

7.1 Network Application 1: Virtual On-Board Unit Provisioning Network Application



Certificate Of Compliance Gold

This is to certify that

OdinS-vOBU-NetworkApplication

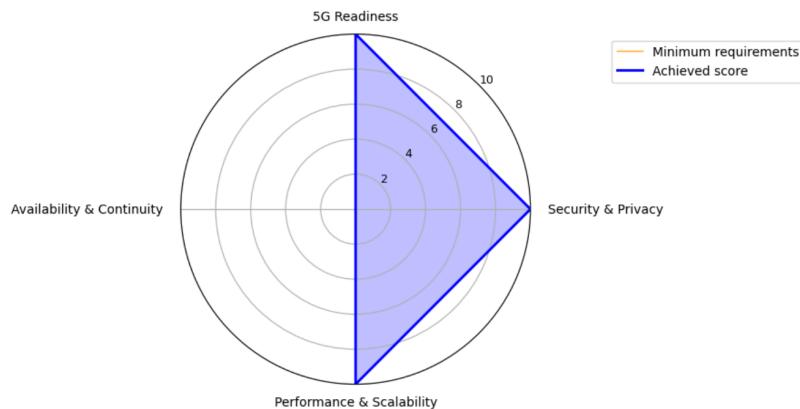
Registered by

OdinS

Under the test conditions

Data plane app
Deployment type VM
Location-based app
Mobility-based app
NEF support
Premium QoS app

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that OdinS-vOBU-NetworkApplication on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result



2024-03-22 14:11:36	5G Readiness	Authentication with 5GS	Conditional	Testbed ITAv	Passed
2024-03-22 14:11:46	5G Readiness	NEF Monitoring Subscription Test	Conditional	Testbed ITAv	Passed
2024-03-22 14:11:56	5G Readiness	NEF Acquisition of UE handover event	Conditional	Testbed ITAv	Passed
2024-03-22 14:12:06	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	Testbed ITAv	Passed
2024-03-22 14:12:16	5G Readiness	Acquisition of UE path loss	Conditional	Testbed ITAv	Passed
2024-03-22 14:12:25	5G Readiness	Acquisition of serving cell information	Conditional	Testbed ITAv	Passed
2024-03-22 14:12:36	5G Readiness	Acquisition of QoS sustainability	Conditional	Testbed ITAv	Passed
2024-03-22 14:09:27	Security & Privacy	Network Application Package Integrity	Conditional	Testbed ITAv	Passed
2024-03-22 14:09:27	Security & Privacy	Network Application should use a security-group offered by testbed	Conditional	Testbed ITAv	Passed
2024-03-22 14:12:44	Security & Privacy	Openstack Port Security	Conditional	Testbed ITAv	Passed
2024-03-22 14:12:55	Security & Privacy	SSL Audit	Conditional	Testbed ITAv	Passed
2024-03-22 14:13:24	Security & Privacy	SSH Brute Force	Conditional	Testbed ITAv	Passed
2024-03-22 14:13:47	Security & Privacy	open ports	Conditional	Testbed ITAv	Passed
2024-03-22 14:13:57	Security & Privacy	SSH Audit	Conditional	Testbed ITAv	Passed
2024-03-22 14:14:06	Security & Privacy	NEF Authentication Test	Conditional	Testbed ITAv	Passed
2024-03-22 14:14:48	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	Testbed ITAv	Passed
2024-03-22 14:15:09	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	Testbed ITAv	Passed
2024-03-22 14:14:26	Performance & Scalability	NEF signalling performance - response time	Conditional	Testbed ITAv	Passed
2024-03-22 14:15:36	Performance & Scalability	NEF signalling performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-22 14:16:03	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-22 14:16:34	Performance & Scalability	Network Application - web performance (static page)	Conditional	Testbed ITAv	Passed
2024-03-22 14:16:45	Performance & Scalability	Network Application - API performance - response time	Conditional	Testbed ITAv	Passed
2024-03-22 14:17:01	Performance & Scalability	Network Application - API performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-22 14:17:29	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-22 14:17:59	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	Testbed ITAv	Passed
2024-03-22 14:18:12	Performance & Scalability	Network Application - IP Traceroute	Mandatory	Testbed ITAv	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Figure 4 - Network Application 1: Virtual On-Board Unit Provisioning Network Application (vOBU) - Certificate

Besides the pre-defined tests that are listed in the application's certificate, OdinS' Virtual On-Board Unit Provisioning (vOBU) Network Application was also validated with 6 developer-defined tests. These tests, as well as their results, are showcased in Figure 5.

27	dev-defined-api_request_test	2024-03-22 14:18:26	2024-03-22 14:18:27	Passed	Test if the Network Application's vOBU is Available	Test Log	Test Report
28	dev-defined-api_request_test	2024-03-22 14:18:36	2024-03-22 14:18:36	Passed	Test if the Network Application's Manager is Available	Test Log	Test Report
29	dev-defined-api_request_test	2024-03-22 14:18:45	2024-03-22 14:18:45	Passed	Test if the Network Application's Aggregator is Available	Test Log	Test Report
30	dev-defined-database_ready_test	2024-03-22 14:18:54	2024-03-22 14:18:54	Passed	Test if the Network Application's vOBU Database is Ready	Test Log	Test Report
31	dev-defined-http_burst_test	2024-03-22 14:19:03	2024-03-22 14:19:03	Passed	Test if the Network Application's Aggregator can Handle a Burst of HTTP Requests	Test Log	Test Report
32	dev-defined-package_check_test	2024-03-22 14:19:14	2024-03-22 14:19:56	Passed	Test if the Network Application's Manager has all Required Software Dependencies	Test Log	Test Report

Figure 5 - Network Application 1: Virtual On-Board Unit Provisioning Network Application (vOBU) - Developer-Defined Tests

7.2 Network Application 2: Virtual Roadside Unit Provisioning Network Application (vRSU)



Certificate Of Compliance Gold

This is to certify that
YoGoKo-vRSU-NetApp

Registered by
YoGoKo

Under the test conditions

Data plane app
Deployment type VM
Location-based app
Mobility-based app
NEF support
Premium QoS app

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that YoGoKo-vRSU-NetApp on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result
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H2020- 101016448

2024-03-19 16:40:36	5G Readiness	Authentication with 5GS	Conditional	Testbed ITAv	Passed
2024-03-19 16:40:45	5G Readiness	NEF Monitoring Subscription Test	Conditional	Testbed ITAv	Passed
2024-03-19 16:40:54	5G Readiness	NEF Acquisition of UE handover event	Conditional	Testbed ITAv	Passed
2024-03-19 16:41:03	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	Testbed ITAv	Passed
2024-03-19 16:41:12	5G Readiness	Acquisition of UE path loss	Conditional	Testbed ITAv	Passed
2024-03-19 16:41:21	5G Readiness	Acquisition of serving cell information	Conditional	Testbed ITAv	Passed
2024-03-19 16:41:32	5G Readiness	Acquisition of QoS sustainability	Conditional	Testbed ITAv	Passed
2024-03-19 16:38:27	Security & Privacy	Network Application Package Integrity	Conditional	Testbed ITAv	Passed
2024-03-19 16:38:27	Security & Privacy	Network Application should use a security-group offered by testbed	Conditional	Testbed ITAv	Passed
2024-03-19 16:41:40	Security & Privacy	Openstack Port Security	Conditional	Testbed ITAv	Passed
2024-03-19 16:41:50	Security & Privacy	SSL Audit	Conditional	Testbed ITAv	Failed
2024-03-19 16:42:01	Security & Privacy	SSH Brute Force	Conditional	Testbed ITAv	Passed
2024-03-19 16:42:13	Security & Privacy	open ports	Conditional	Testbed ITAv	Passed
2024-03-19 16:42:23	Security & Privacy	SSH Audit	Conditional	Testbed ITAv	Passed
2024-03-19 16:42:32	Security & Privacy	NEF Authentication Test	Conditional	Testbed ITAv	Passed
2024-03-19 16:43:13	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	Testbed ITAv	Passed
2024-03-19 16:43:32	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	Testbed ITAv	Passed
2024-03-19 16:42:52	Performance & Scalability	NEF signalling performance - response time	Conditional	Testbed ITAv	Passed
2024-03-19 16:43:59	Performance & Scalability	NEF signalling performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-19 16:44:26	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-19 16:44:56	Performance & Scalability	Network Application - web performance (static page)	Conditional	Testbed ITAv	Passed
2024-03-19 16:45:08	Performance & Scalability	Network Application - API performance - response time	Conditional	Testbed ITAv	Passed
2024-03-19 16:45:23	Performance & Scalability	Network Application - API performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-19 16:45:49	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-19 16:46:20	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	Testbed ITAv	Passed
2024-03-19 16:46:33	Performance & Scalability	Network Application - IP Traceroute	Mandatory	Testbed ITAv	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Figure 6 - Network Application 2: Virtual Roadside Unit Provisioning Network Application (VRSU) - Certificate

7.3 Network Application 3: C-ITS Station Network Application



Certificate Of Compliance Gold

This is to certify that

YoGoKo-CITS-NetApp

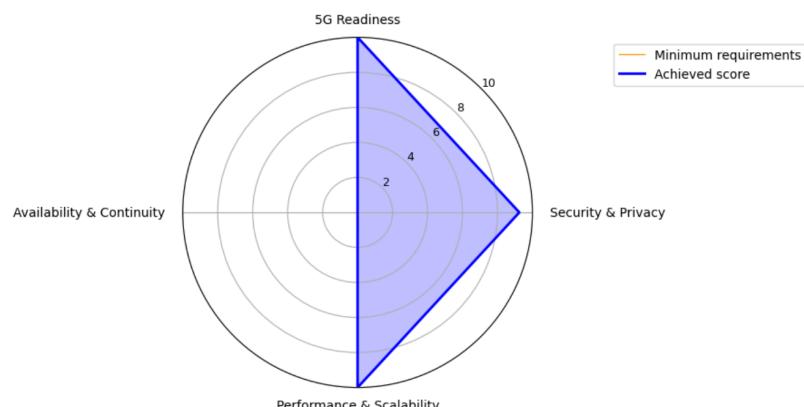
Registered by

YoGoKo

Under the test conditions

Data plane app
Deployment type VM
Location-based app
Mobility-based app
NEF support
Premium QoS app

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that YoGoKo-CITS-NetApp on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result



2024-03-19 15:54:52	5G Readiness	Authentication with 5GS	Conditional	Testbed ITAv	Passed
2024-03-19 15:55:02	5G Readiness	NEF Monitoring Subscription Test	Conditional	Testbed ITAv	Passed
2024-03-19 15:55:11	5G Readiness	NEF Acquisition of UE handover event	Conditional	Testbed ITAv	Passed
2024-03-19 15:55:20	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	Testbed ITAv	Passed
2024-03-19 15:55:29	5G Readiness	Acquisition of UE path loss	Conditional	Testbed ITAv	Passed
2024-03-19 15:55:38	5G Readiness	Acquisition of serving cell information	Conditional	Testbed ITAv	Passed
2024-03-19 15:55:48	5G Readiness	Acquisition of QoS sustainability	Conditional	Testbed ITAv	Passed
2024-03-19 15:52:43	Security & Privacy	Network Application Package Integrity	Conditional	Testbed ITAv	Passed
2024-03-19 15:52:43	Security & Privacy	Network Application should use a security-group offered by testbed	Conditional	Testbed ITAv	Passed
2024-03-19 15:55:56	Security & Privacy	Openstack Port Security	Conditional	Testbed ITAv	Passed
2024-03-19 15:56:07	Security & Privacy	SSL Audit	Conditional	Testbed ITAv	Failed
2024-03-19 15:56:17	Security & Privacy	SSH Brute Force	Conditional	Testbed ITAv	Passed
2024-03-19 15:56:29	Security & Privacy	open ports	Conditional	Testbed ITAv	Passed
2024-03-19 15:56:39	Security & Privacy	SSH Audit	Conditional	Testbed ITAv	Passed
2024-03-19 15:56:48	Security & Privacy	NEF Authentication Test	Conditional	Testbed ITAv	Passed
2024-03-19 15:57:29	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	Testbed ITAv	Passed
2024-03-19 15:57:48	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	Testbed ITAv	Passed
2024-03-19 15:57:08	Performance & Scalability	NEF signalling performance - response time	Conditional	Testbed ITAv	Passed
2024-03-19 15:58:13	Performance & Scalability	NEF signalling performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-19 15:58:41	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-19 15:59:11	Performance & Scalability	Network Application - web performance (static page)	Conditional	Testbed ITAv	Passed
2024-03-19 15:59:23	Performance & Scalability	Network Application - API performance - response time	Conditional	Testbed ITAv	Passed
2024-03-19 15:59:38	Performance & Scalability	Network Application - API performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-19 16:00:04	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-19 16:00:35	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	Testbed ITAv	Passed
2024-03-19 16:00:48	Performance & Scalability	Network Application - IP Traceroute	Mandatory	Testbed ITAv	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Figure 7 - Network Application 3: C-ITS Station Network Application - Certificate

7.4 Network Application 4: Multi-Domain Migration Network Application



Certificate Of Compliance Gold

This is to certify that

OdinS-Migrate-NetworkApplication

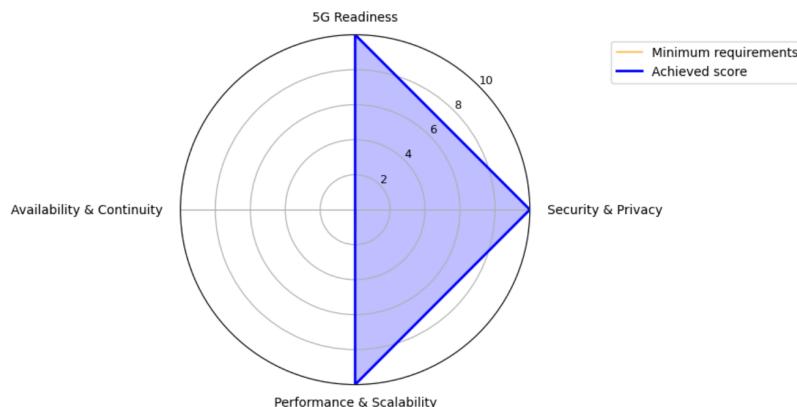
Registered by

OdinS

Under the test conditions

Data plane app
Deployment type VM
Location-based app
Mobility-based app
NEF support

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that OdinS-Migrate-NetworkApplication on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result
2024-03-22 14:34:15	5G Readiness	Authentication with 5GS	Conditional	Testbed ITAv	Passed



2024-03-22 14:34:25	5G Readiness	NEF Monitoring Subscription Test	Conditional	Testbed ITAv	Passed
2024-03-22 14:34:34	5G Readiness	NEF Acquisition of UE handover event	Conditional	Testbed ITAv	Passed
2024-03-22 14:34:43	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	Testbed ITAv	Passed
2024-03-22 14:34:54	5G Readiness	Acquisition of UE path loss	Conditional	Testbed ITAv	Passed
2024-03-22 14:35:03	5G Readiness	Acquisition of serving cell information	Conditional	Testbed ITAv	Passed
2024-03-22 14:32:06	Security & Privacy	Network Application Package Integrity	Conditional	Testbed ITAv	Passed
2024-03-22 14:32:06	Security & Privacy	Network Application should use a security-group offered by testbed	Conditional	Testbed ITAv	Passed
2024-03-22 14:35:13	Security & Privacy	Openstack Port Security	Conditional	Testbed ITAv	Passed
2024-03-22 14:35:23	Security & Privacy	SSL Audit	Conditional	Testbed ITAv	Passed
2024-03-22 14:35:51	Security & Privacy	SSH Brute Force	Conditional	Testbed ITAv	Passed
2024-03-22 14:36:14	Security & Privacy	open ports	Conditional	Testbed ITAv	Passed
2024-03-22 14:36:24	Security & Privacy	SSH Audit	Conditional	Testbed ITAv	Passed
2024-03-22 14:36:34	Security & Privacy	NEF Authentication Test	Conditional	Testbed ITAv	Passed
2024-03-22 14:37:15	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	Testbed ITAv	Passed
2024-03-22 14:37:36	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	Testbed ITAv	Passed
2024-03-22 14:36:54	Performance & Scalability	NEF signalling performance - response time	Conditional	Testbed ITAv	Passed
2024-03-22 14:38:03	Performance & Scalability	NEF signalling performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-22 14:38:30	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-22 14:39:01	Performance & Scalability	Network Application - web performance (static page)	Conditional	Testbed ITAv	Passed
2024-03-22 14:39:12	Performance & Scalability	Network Application - API performance - response time	Conditional	Testbed ITAv	Passed
2024-03-22 14:39:27	Performance & Scalability	Network Application - API performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-22 14:39:55	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-22 14:40:25	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	Testbed ITAv	Passed
2024-03-22 14:40:38	Performance & Scalability	Network Application - IP Traceroute	Mandatory	Testbed ITAv	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Figure 8 - Network Application 4: Multi-Domain Migration Network Application - Certificate

Besides the pre-defined tests that are listed in the application's certificate, OdinS' Multi-Domain Migration Network Application was also validated with 6 developer-defined tests. These tests, as well as their results, are showcased in Figure 9.

27	dev-defined-api_request_test	2024-03-22 14:18:26	2024-03-22 14:18:27	Passed	Test if the Network Application's vOBU is Available	Test Log	Test Report
28	dev-defined-api_request_test	2024-03-22 14:18:36	2024-03-22 14:18:36	Passed	Test if the Network Application's Manager is Available	Test Log	Test Report
29	dev-defined-api_request_test	2024-03-22 14:18:45	2024-03-22 14:18:45	Passed	Test if the Network Application's Aggregator is Available	Test Log	Test Report
30	dev-defined-database_ready_test	2024-03-22 14:18:54	2024-03-22 14:18:54	Passed	Test if the Network Application's vOBU Database is Ready	Test Log	Test Report
31	dev-defined-http_burst_test	2024-03-22 14:19:03	2024-03-22 14:19:03	Passed	Test if the Network Application's Aggregator can Handle a Burst of HTTP Requests	Test Log	Test Report
32	dev-defined-package_check_test	2024-03-22 14:19:14	2024-03-22 14:19:56	Passed	Test if the Network Application's Manager has all Required Software Dependencies	Test Log	Test Report

Figure 9 - Network Application 4: Multi-Domain Migration Network Application - Developer-Defined Tests

7.5 Network Application 5: Vehicle-to-Cloud (V2C) Real-Time Communication Network Application

At the time of closure of this document, the testing of the Vehicle-to-Cloud (V2C) Real-Time Communication Network Application was still ongoing. Therefore, it was not possible to certify this Network Application through the 5GASP CI/CD and Certification Pipeline, and, as such, no certification results are showcased in this section.

7.6 Network Application 6: Remote Human Driving Network Application - Teleoperation for Assisting Vehicles in Complex Situation

At the time of closure of this document, the testing of the Remote Human Driving Network Application (Teleoperation for Assisting Vehicles in Complex Situation) was still ongoing. Thus, it was not possible to certify this Network Application through the 5GASP CI/CD and Certification Pipeline, and, therefore, no certification results are presented in this section.

7.7 Network Application 7: Efficient MEC Handover Network Application



Certificate Of Compliance Silver

This is to certify that

UoB-EfficientMEC-NetworkApplication

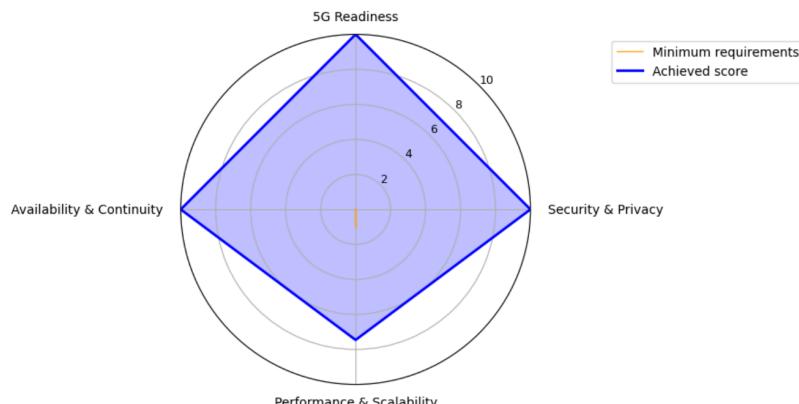
Registered by

UoB

Under the test conditions

Data plane app
Deployment type Container
Location-based app
Mobility-based app
NEF support
Premium QoS app

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that UoB-EfficientMEC-NetworkApplication on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result



2024-03-27 13:17:26	5G Readiness	Authentication with 5GS	Conditional	UoP - Testbed	Passed
2024-03-27 13:17:34	5G Readiness	NEF Monitoring Subscription Test	Conditional	UoP - Testbed	Passed
2024-03-27 13:17:41	5G Readiness	NEF Acquisition of UE handover event	Conditional	UoP - Testbed	Passed
2024-03-27 13:17:49	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	UoP - Testbed	Passed
2024-03-27 13:17:57	5G Readiness	Acquisition of UE path loss	Conditional	UoP - Testbed	Passed
2024-03-27 13:18:04	5G Readiness	Acquisition of serving cell information	Conditional	UoP - Testbed	Passed
2024-03-27 13:18:12	5G Readiness	Acquisition of QoS sustainability	Conditional	UoP - Testbed	Passed
2024-03-27 13:18:20	Security & Privacy	NEF Authentication Test	Conditional	UoP - Testbed	Passed
2024-03-27 13:18:27	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	UoP - Testbed	Passed
2024-03-27 13:18:46	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	UoP - Testbed	Passed
2024-03-27 13:19:10	Performance & Scalability	NEF signalling performance - response time	Conditional	UoP - Testbed	Failed
2024-03-27 13:19:34	Performance & Scalability	NEF signalling performance - requests per second	Conditional	UoP - Testbed	Passed
2024-03-27 13:19:57	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	UoP - Testbed	Failed
2024-03-27 13:20:25	Performance & Scalability	Network Application - web performance (static page)	Conditional	UoP - Testbed	Passed
2024-03-27 13:20:34	Performance & Scalability	Network Application - API performance - response time	Conditional	UoP - Testbed	Passed
2024-03-27 13:20:46	Performance & Scalability	Network Application - API performance - requests per second	Conditional	UoP - Testbed	Passed
2024-03-27 13:21:10	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	UoP - Testbed	Failed
2024-03-27 13:21:38	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	UoP - Testbed	Passed
2024-03-27 13:21:49	Performance & Scalability	Network Application - IP Traceroute	Mandatory	UoP - Testbed	Passed
2024-03-27 13:22:01	Availability & Continuity	Network Application continues its proper functioning after restricted bandwidth scenario	Conditional	UoP - Testbed	Passed
2024-03-27 13:23:30	Availability & Continuity	Network Application continues its proper functioning after an introduced delay scenario	Conditional	UoP - Testbed	Passed
2024-03-27 13:24:58	Availability & Continuity	Network Application continues its proper functioning after an introduced packet loss scenario	Conditional	UoP - Testbed	Passed
2024-03-27 13:26:27	Availability & Continuity	Network Application continues its proper functioning after an introduced packet corruption scenario	Conditional	UoP - Testbed	Passed
2024-03-27 13:27:56	Availability & Continuity	Network Application continues its proper functioning after an introduced total disruption of communication scenario	Conditional	UoP - Testbed	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Observations [optional]: Deployment details can be viewed [here](#) on 5GASP NODS.

Figure 10 - Network Application 7: Efficient MEC Handover Network Application - Certificate

7.8 Network Application 8: Privacy Analyzer Network Application



Certificate Of Compliance Gold

This is to certify that

LamdaNetworks-PrivacyAnalyzer-NetworkApplication

Registered by

LamdaNetworks

Under the test conditions

NEF support

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that LamdaNetworks-PrivacyAnalyzer-NetworkApplication on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result
2024-03-26 11:33:18	5G Readiness	Authentication with 5GS	Conditional	Testbed ITAv	Passed
2024-03-26 11:33:28	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	Testbed ITAv	Passed
2024-03-26 11:33:39	5G Readiness	Acquisition of UE path loss	Conditional	Testbed ITAv	Passed



2024-03-26 11:33:48	5G Readiness	Acquisition of serving cell information	Conditional	Testbed ITAv	Passed
2024-03-26 11:33:58	Security & Privacy	NEF Authentication Test	Conditional	Testbed ITAv	Passed
2024-03-26 11:34:15	Performance & Scalability	NEF signalling performance - response time	Conditional	Testbed ITAv	Passed
2024-03-26 11:34:42	Performance & Scalability	NEF signalling performance - requests per second	Conditional	Testbed ITAv	Passed
2024-03-26 11:35:09	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	Testbed ITAv	Passed
2024-03-26 11:35:40	Performance & Scalability	Network Application - IP Traceroute	Mandatory	Testbed ITAv	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Observations [optional]: Deployment details can be viewed [here](#) on 5GASP NODS.

This document was created on 26/03/2024.

5GASP - This project has received funding from the European Union's Horizon 2020 research and innovation programme (5GASP H2020 – ICT- 2020). Grant agreement ID: 101016448



Figure 11 - Network Application 8: Privacy Analyzer Network Application - Certificate

Besides the pre-defined tests that are listed in the application's certificate, Lamda Networks' Privacy Analyzer Network Application was also validated with 3 developer-defined tests. These tests, as well as their results, are showcased in Figure 12.

11	dev-defined-api_server_test	2024-03-26 11:35:54	2024-03-26 11:35:54	Passed	Test if the Network Application's API is Available	Test Log	Test Report
12	dev-defined-db_server_test	2024-03-26 11:36:03	2024-03-26 11:36:03	Passed	Test if the Network Application's Database is Available	Test Log	Test Report
13	dev-defined-connectivity_with_ues_test	2024-03-26 11:36:12	2024-03-26 11:36:12	Passed	Test if the Network Application receives messages from the UEs	Test Log	Test Report

Figure 12 - Network Application 8: Privacy Analyzer Network Application - Developer-Defined Tests

7.9 Network Application 9: Isolated Operation for Public Safety (IOPS) Network Application



Certificate Of Compliance Gold

This is to certify that

ININ-IOPS-NetworkApplication

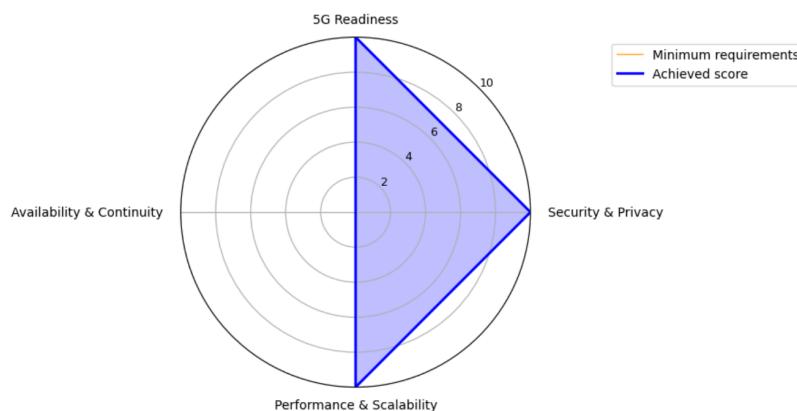
Registered by

ININ

Under the test conditions

Data plane app
NEF support
Premium QoS app

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that ININ-IOPS-NetworkApplication on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result
2024-03-20 20:09:36	5G Readiness	Authentication with 5GS	Conditional	ININ - Testbed	Passed
2024-03-20 20:09:48	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	ININ - Testbed	Passed



2024-03-20 20:10:02	5G Readiness	Acquisition of UE path loss	Conditional	ININ - Testbed	Passed
2024-03-20 20:10:13	5G Readiness	Acquisition of serving cell information	Conditional	ININ - Testbed	Passed
2024-03-20 20:10:27	5G Readiness	Acquisition of QoS sustainability	Conditional	ININ - Testbed	Passed
2024-03-20 20:10:38	Security & Privacy	NEF Authentication Test	Conditional	ININ - Testbed	Passed
2024-03-20 20:10:54	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	ININ - Testbed	Passed
2024-03-20 20:11:18	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	ININ - Testbed	Passed
2024-03-20 20:14:17	Performance & Scalability	NEF signalling performance - response time	Conditional	ININ - Testbed	Passed
2024-03-20 20:14:49	Performance & Scalability	NEF signalling performance - requests per second	Conditional	ININ - Testbed	Passed
2024-03-20 20:15:22	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	ININ - Testbed	Passed
2024-03-20 20:11:40	Performance & Scalability	Network Application - web performance (static page)	Conditional	ININ - Testbed	Passed
2024-03-20 20:11:54	Performance & Scalability	Network Application - API performance - response time	Conditional	ININ - Testbed	Passed
2024-03-20 20:12:14	Performance & Scalability	Network Application - API performance - requests per second	Conditional	ININ - Testbed	Passed
2024-03-20 20:12:47	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	ININ - Testbed	Passed
2024-03-20 20:13:19	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	ININ - Testbed	Passed
2024-03-20 20:13:35	Performance & Scalability	Network Application - IP Traceroute	Mandatory	ININ - Testbed	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Figure 13 - Network Application 9: Isolated Operation for Public Safety (IOPS) Network Application - Certificate

Besides the pre-defined tests that are listed in the application's certificate, ININ's Isolated Operation for Public Safety (IOPS) Network Application was also validated with 3 developer-defined tests. These tests, as well as their results, are showcased in Figure 14.

20	dev-defined-iops_basic_check	2024-03-20 20:15:56	2024-03-20 20:15:57	Passed	Test IOPS CN Component readiness	Test Log	Test Report
21	dev-defined-iops_ue_internet_check	2024-03-20 20:16:09	2024-03-20 20:16:17	Passed	Test IOPS Internet connectivity test	Test Log	Test Report
22	dev-defined-iops_ue_local_check	2024-03-20 20:16:29	2024-03-20 20:17:12	Passed	Test IOPS Local connectivity test	Test Log	Test Report

Figure 14 - Network Application 9: Isolated Operation for Public Safety (IOPS) Network Application - Developer-Defined Tests

7.10 Network Application 10: Vehicle Route Optimizer Network Application



Certificate Of Compliance Gold

This is to certify that

Neobility-VRO-NetworkApplication

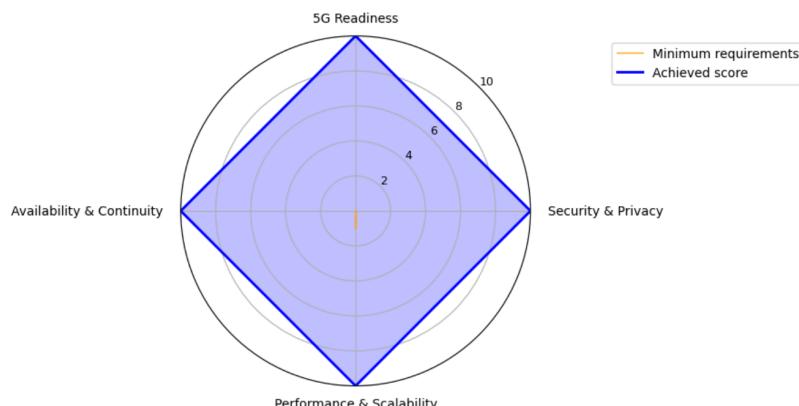
Registered by

Neobility

Under the test conditions

Data plane app
Deployment type Container
Location-based app
Mobility-based app
NEF support

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that Neobility-VRO-NetworkApplication on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result
2024-03-26 17:10:21	5G Readiness	Authentication with 5GS	Conditional	UoP - Testbed	Passed



2024-03-26 17:10:29	5G Readiness	NEF Monitoring Subscription Test	Conditional	UoP - Testbed	Passed
2024-03-26 17:10:36	5G Readiness	NEF Acquisition of UE handover event	Conditional	UoP - Testbed	Passed
2024-03-26 17:10:42	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	UoP - Testbed	Passed
2024-03-26 17:10:50	5G Readiness	Acquisition of UE path loss	Conditional	UoP - Testbed	Passed
2024-03-26 17:10:57	5G Readiness	Acquisition of serving cell information	Conditional	UoP - Testbed	Passed
2024-03-26 17:11:05	Security & Privacy	NEF Authentication Test	Conditional	UoP - Testbed	Passed
2024-03-26 17:11:16	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	UoP - Testbed	Passed
2024-03-26 17:11:34	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	UoP - Testbed	Passed
2024-03-26 17:11:59	Performance & Scalability	NEF signalling performance - response time	Conditional	UoP - Testbed	Passed
2024-03-26 17:12:23	Performance & Scalability	NEF signalling performance - requests per second	Conditional	UoP - Testbed	Passed
2024-03-26 17:12:46	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	UoP - Testbed	Passed
2024-03-26 17:13:15	Performance & Scalability	Network Application - web performance (static page)	Conditional	UoP - Testbed	Passed
2024-03-26 17:13:24	Performance & Scalability	Network Application - API performance - response time	Conditional	UoP - Testbed	Passed
2024-03-26 17:13:36	Performance & Scalability	Network Application - API performance - requests per second	Conditional	UoP - Testbed	Passed
2024-03-26 17:13:59	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	UoP - Testbed	Passed
2024-03-26 17:14:27	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	UoP - Testbed	Passed
2024-03-26 17:14:37	Performance & Scalability	Network Application - IP Traceroute	Mandatory	UoP - Testbed	Passed
2024-03-26 17:14:50	Availability & Continuity	Network Application continues its proper functioning after restricted bandwidth scenario	Conditional	UoP - Testbed	Passed
2024-03-26 17:16:19	Availability & Continuity	Network Application continues its proper functioning after an introduced delay scenario	Conditional	UoP - Testbed	Passed
2024-03-26 17:17:47	Availability & Continuity	Network Application continues its proper functioning after an introduced packet loss scenario	Conditional	UoP - Testbed	Passed
2024-03-26 17:19:16	Availability & Continuity	Network Application continues its proper functioning after an introduced packet corruption scenario	Conditional	UoP - Testbed	Passed
2024-03-26 17:20:45	Availability & Continuity	Network Application continues its proper functioning after an introduced total disruption of communication scenario	Conditional	UoP - Testbed	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Observations [optional]: Deployment details can be viewed [here](#) on 5GASP NODS.

This document was created on 26/03/2024.

Figure 15 - Network Application 10: Vehicle Route Optimizer Network Application - Certificate

Besides the pre-defined tests that are listed in the application's certificate, Neobility's Vehicle Route Optimizer Network Application was also validated with 3 developer-defined tests. These tests, as well as their results, are showcased in Figure 16.

26	dev-defined-main_api_test	2024-03-26 17:22:14	2024-03-26 17:22:15	Passed	Test if VRO's Main API is available	Test Log	Test Report
27	dev-defined-neo_routing_engine_test	2024-03-26 17:22:22	2024-03-26 17:22:22	Passed	Test if VRO's Routing Engine is behaving as expected	Test Log	Test Report
28	dev-defined-neo_transport_api_test	2024-03-26 17:22:29	2024-03-26 17:22:29	Passed	Test if VRO's Transport API is available	Test Log	Test Report
29	dev-defined-osrm_test	2024-03-26 17:22:35	2024-03-26 17:22:36	Passed	Test if VRO's OSRM is behaving as expected	Test Log	Test Report

Figure 16 - Network Application 10: Vehicle Route Optimizer Network Application - Developer-Defined Tests

7.11 Network Application 11: Fire Detection and Ground Assistance Using Drones



Certificate Of Compliance Gold

This is to certify that

UoP-FIDEGAD-NetworkApplication

Registered by

UoP

Under the test conditions

Data plane app
Deployment type Container
Location-based app
Mobility-based app
NEF support
Premium QoS app

Has been developed in accordance with the 5G Application and Services experimentation and certification Platform (5GASP) guidelines.



The 5GASP Certification board verified that UoP-FIDEGAD-NetworkApplication on its version 1.0 has successfully passed the 5GASP-C certification criteria under the following scenarios:

Date	Axis	Name of test**	Type of test	Testbed of experimentation / Execution Partner	Test result



102

H2020- 101016448

2024-03-26 20:06:53	5G Readiness	Authentication with 5GS	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:00	5G Readiness	NEF Monitoring Subscription Test	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:08	5G Readiness	NEF Acquisition of UE handover event	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:15	5G Readiness	Acquisition of UE Received Signal Power (RSRP) information	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:22	5G Readiness	Acquisition of UE path loss	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:29	5G Readiness	Acquisition of serving cell information	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:37	5G Readiness	Acquisition of QoS sustainability	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:44	Security & Privacy	NEF Authentication Test	Conditional	UoP - Testbed	Passed
2024-03-26 20:07:51	Performance & Scalability	E2E download/upload Internet Protocol (IP) throughput & latency performance, single UE	Conditional	UoP - Testbed	Passed
2024-03-26 20:08:04	Performance & Scalability	E2E download/upload IP throughput & latency performance, multiple UE	Conditional	UoP - Testbed	Passed
2024-03-26 20:08:20	Performance & Scalability	NEF signalling performance - response time	Conditional	UoP - Testbed	Passed
2024-03-26 20:08:44	Performance & Scalability	NEF signalling performance - requests per second	Conditional	UoP - Testbed	Passed
2024-03-26 20:09:08	Performance & Scalability	NEF signalling performance - maximum number of connections	Conditional	UoP - Testbed	Passed
2024-03-26 20:09:37	Performance & Scalability	Network Application - web performance (static page)	Conditional	UoP - Testbed	Passed
2024-03-26 20:09:45	Performance & Scalability	Network Application - API performance - response time	Conditional	UoP - Testbed	Passed
2024-03-26 20:09:57	Performance & Scalability	Network Application - API performance - requests per second	Conditional	UoP - Testbed	Passed
2024-03-26 20:10:21	Performance & Scalability	Network Application - API performance - maximum number of connections	Conditional	UoP - Testbed	Passed
2024-03-26 20:10:49	Performance & Scalability	Network Application - IP Round-trip time (RTT)	Conditional	UoP - Testbed	Passed
2024-03-26 20:11:00	Performance & Scalability	Network Application - IP Traceroute	Mandatory	UoP - Testbed	Passed
2024-03-26 20:11:12	Availability & Continuity	Network Application continues its proper functioning after restricted bandwidth scenario	Conditional	UoP - Testbed	Passed
2024-03-26 20:12:41	Availability & Continuity	Network Application continues its proper functioning after an introduced delay scenario	Conditional	UoP - Testbed	Passed
2024-03-26 20:14:09	Availability & Continuity	Network Application continues its proper functioning after an introduced packet loss scenario	Conditional	UoP - Testbed	Passed
2024-03-26 20:15:38	Availability & Continuity	Network Application continues its proper functioning after an introduced packet corruption scenario	Conditional	UoP - Testbed	Passed
2024-03-26 20:17:07	Availability & Continuity	Network Application continues its proper functioning after an introduced total disruption of communication scenario	Conditional	UoP - Testbed	Passed

** For more details, please check the test description [here](#) on 5GASP CI/CD Service.

Observations [optional]: Deployment details can be viewed [here](#) on 5GASP NODS.

Figure 17- Network Application 11: Fire Detection and Ground Assistance Using Drones (FIDEGAD) - Certificate

8 Conclusions and Lessons Learned

8.1 Tests Definition Process Lessons Learned

Throughout the process of the tests definition and creation that would be generalized and inclusive for all Network Applications, we have found multiple challenges.

The variety of Network Applications with their different purposes, functionalities, architectures, and implementations posed the challenge of creating generalized tests that could be applicable to all Network Applications. Some Network Applications are implemented in virtual machines, others in containers. Some are centralized in one entity, others are distributed and consist of multiple components. Some use NEF, others do not, and so on. To accommodate this variety, we introduced four different test areas to show how well a Network Application performs in each (applicable) area. The test areas are:

- 5G Readiness;
- Security & Privacy;
- Performance & Scalability;
- Availability & Continuity.

This classification helped us cover all possible aspects of the Network Applications testing but also introduced difficulties, such as unbalanced test coverage for each area. EANTC and the partners worked together to define a balanced number of tests for each area that would be applicable to most of the Network Applications.

At first, we only considered tests to be either mandatory or optional. However, we realized that only a few tests were actually applicable to all Network Applications and, thus, could be mandatory. To ensure that each Network Application is tested thoroughly while also taking into account its specifics, we introduced test conditions (e.g., NEF support, location-based app, etc.). Instead of optional tests, we now have conditional mandatory tests, where each test is assigned a list of test conditions. During the certification testing, a Network Application must now execute additional conditional tests based on its selected test conditions.

8.2 Test Execution Lessons Learned

Several challenges arose during the test execution. The most difficult one was controlling the applications' lifecycle during the testing phase, especially given that in the 5GASP project, Network Applications are tested as black boxes. To overcome this, we have introduced the Network Application Control MiniAPI. This API provides a collection of endpoints through which it is possible to trigger specific operations on the Network Application. Therefore, it allows us to control the lifecycle of these operations during the testing phase. All Network

Application developers were asked to integrate this API with their Applications, which was successfully achieved, as showcased by the certification results in Section 7.

Another complexity that the 5GASP project dealt with was defining a methodology to validate the interaction between Network Applications and the 5G System. In 5GASP, we assume that the Network Applications will interact with the 5G Network through the NEF. Therefore, it was necessary to validate this interaction. This was made possible by relying on NEFSim, an open-source NEF Simulator developed in the EVOLVED-5G project. Still, even when relying on this tool, it was impossible to validate that the Network Applications correctly interacted with the NEF. The solution to this problem relied on developing a Reporting API that sits on top of the NEF simulator and records and monitors all requests received by the NEF as well as the responses provided by the NEF and the source of the request. The Reporting API then offers a report that comprises all interactions with the NEF, and it is through this report that we validate if the interaction between the applications and the NEF was achieved. This approach is what made the definition of all certification tests that lie under the 5G Readiness test axis possible.

Lastly, 5GASP also faced several challenges to ensure that all Network Applications could be deployed in all testbeds. To accommodate this, all testbed owners prepared their infrastructure using a similar approach. As an example, we may point out the undertaken preparations to allow for the deployment of CNFs in Kubernetes: every testbed defined a secret in a specific namespace. This secret makes it possible for Kubernetes to obtain the CNF Helm Charts and containers from the 5GASP Harbor. Therefore, the applications had to be deployed in a specific Kubernetes namespace defined by the testbeds. Moreover, a similar approach was taken when dealing with VNFs. All testbeds provided a list of the available networks where the applications could be deployed, and the Network Application developers adapted their applications to adhere to the offered networks.

The lessons learned, above, in regard to both the definition and adaptation of the testing procedures, in order to accommodate for our testing platforms were very well placed for us to give a background needed on the work ensued and entailed for the implementation and deployment of a large, international, automated testing platform for 5G technologies and applications, such as the 5GASP Platform.

Appendix A

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-Type request 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 Accept request header; the media type will be conveyed by the Content-Type response header.

- text/plain

Responses

201

item created, returning ID [Integer](#)

400

cannot create stream,

409

invalid input, values out of bounds

```
>
```

[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 Accept request header; the media type will be conveyed by the Content-Type response header.

- application/json

Responses

200

info and config details of networkApp [NetworkAppInfo](#)

400

no info available

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

Models

[Jump to [Methods](#)]

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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, "D5.4 Initial Report for the Network Application certification testing," March 2023. [Online].
- [2] 5GASP, "D5.1 Initial Report on Test Plan Creation and Testing Methodologies," September 2021. [Online].
- [3] 5GASP, "D5.2 Integration guide and API reference manual," January 2023. [Online].
- [4] 5GASP, "D5.3 Development of testing tools and framework for the Automotive and PPDR Verticals," October 2023. [Online].
- [5] 5GASP, "D6.3 Final progress report on Network Applications Community & Certification process," March 2024. [Online].
- [6] 5GASP, "D6.2 Interim progress report on NetApps Community & Certification process," March 2023. [Online].
- [7] 5GASP, "D2.1 Architecture, Model Entities Specification and Design," March 2021. [Online].