

Security and Trust in the Integration of Network Functions within the 5G Architecture: The 5GASP Project

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Abstract

Given the mature status of 5G infrastructures, it is the moment for their enhancement through the integration of novel network functions that will enable novel functionalities. This market is open for big companies, small and medium enterprises (SMEs), and practitioners, which will bring their experience and innovative ideas for continue developing the 5G ecosystem. However, the integration of third party network functions should follow a rigorous process for ensuring the security and stability of the hosting network. To this end, the European H2020-funded project 5GASP is developing an unified methodology to define the design, development, and onboarding of Network Applications (NetApps) within the scope of different vertical services. The principal aim of this work is to present such methodology as well as the main objectives of the project. The presented workflow allows a meticulous evaluation and certification of novel NetApps prior to their deployment in functional 5G systems.

1 Introduction

The development, deployment, and integration of innovative network functions within 5G infrastructures is an upcoming niche market to be exploited by the telecommunication industry, including SMEs, developers, etc. Nevertheless, infrastructure operators should have adequate tools for analyzing and testing these Virtualized Network Functions (VNFs) [3] before their integration within production systems. To this end, the European H2020-funded project 5GASP¹ is putting great efforts on easing the idea-to-market process through the creation of an European testbed that is fully automated and self-service, aiming at fueling the efficient development and evaluation of novel NetApps built using the 5G NFV based reference architecture. In the following, we present the main objectives of 5GASP.

1.1 5GASP Objectives

The first aim of the project is the acceleration of the development, testing, and certification of 5G Network Applications (NetApps), through the creation of a common platform, Development and Operations (DevOps) tools and a certification roadmap. To reduce the time-to-market for novel NetApps from third party developers, an integrated DevOps methodology is the most adequate procedure. Furthermore, 5GASP will address the challenges of validation, verification and certification of NetApps, so that operators are aware of their behaviour before deploying them on their production network. To achieve all the above, 5GASP introduces novel procedures and a novel fully automated toolchain that caters for the production of any NetApp without any human interaction.

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¹<https://5g-ppp.eu/5gasp/>

For this to be done, 5GASP will provide state-of-the-art testbeds where applications for relevant verticals can be tested and validated in a cost-effective way. This is another key objective of the project, which is building an open and inter-domain 5G NFV-based ecosystem of experimental facilities on top of existing 5G infrastructures developed in previous projects such as 5GinFIRE², 5G VINNI³, or MATILDA⁴, among others. Thanks to this heterogeneous set of testbeds, 5GASP will address inter-domain use-cases, and security and trust aspects associated with NetApp DevOps. In 5GASP these issues are pragmatically addressed from the viewpoint of the companies developing and deploying their NetApps, requiring safety for their intellectual property rights (IPR) and from the viewpoint of the network operator which must trust on the correct and limited behaviour of the NetApp in its network.

Another important aspect tackled by the project is the automation of the testing and validation process, lowering costs associated with testing and certification of NetApps in telecommunication environments. In 5GASP, the focus is on providing the blueprints for all the stakeholders in the ecosystem, in accordance with their capabilities, to be able to setup automated testing of NetApps. In this line, it is crucial to provide all the community with state-of-the-art tools for test deployment, test automation, continuous integration and monitoring of testbeds, mainly through Open Source Software (OSS) tools. Therefore, 5GASP plans the development of software tools that can assist the NetApp developers in building Continuous Integrations frameworks, targeted at their specific vertical, consisting mostly out of OSS tools and producing reports that can be used to start certification processes.

Finally, 5GASP aims at creating a business model around a marketplace of NetApps, by which all stakeholders can share revenue. The purpose of this portal is to promote the developers and their respective NetApps as well as the platforms and operators that support them. Furthermore, this portal has the potential to be marketed in a way similar to stores for mobile apps, such as Apples' store, Google Play and Huawei store. Besides, the portal will include information of tests/validations the NetApps have successfully passed, as well as testbeds and network operators that have deployed successfully the NetApp.

The purpose of this work is presenting the unified methodology approach to design and develop NetApps within the scope of the 5GASP project. The intention of the proposed methodology is to establish how 5GASP solutions will be defined, modeled, designed, and implemented to conform a NetApp to be automated, integrated and tested in the envisioned Continuous Integration and Continuous Delivery (CI/CD) process. Thereafter, we describe how the NetApps are managed in the 5GASP platform and the families in which they can be categorized.

The rest of the document is organized as follows. Section 2 describes the design and development stages of a Netapp. The NetApp management process is presented in Section 3. The paper is concluded in Section 4 which also presents the next steps that will be taken within the context of the 5GASP project.

2 NetApp Design and Development Methodology

In the following, the NetApp design and development methodology that is followed in the 5GASP project is presented. The objective of defining a design and development methodology is motivated by the need of bringing the NetApp developers and the 5G ecosystem together. In this way, the methodology will reduce the time and costs of making new 5G NetApps, or adapting the existing ones to these new technologies.

²<https://5ginfire.eu/>

³<https://www.5g-vinni.eu/>

⁴<https://www.matilda-5g.eu/>

2.1 Design

Certain considerations should be taken into account by a NetApp developer when designing a network function to be onboarded in the 5GASP environment. This is necessary in order to ensure that the 5GASP framework is able to adequately deploy and evaluate the different NetApp components. The design phase is divided in three different steps, as shown in Fig. 1. Firstly, the main components of the NetApp should be defined in terms of services and interworking service components, in other words, VNFs in the 5G terminology. This is done by using Network Service Descriptors (NSDs). Therefore, each NetApp should be split into the different VNFs composing it, and the relation among them is described by using NSDs. In this first step, the programmer should also define the cardinality between VNFs and NSDs given that an NSD can consist of more than one VNFs. The NSD shall thoroughly describe the network service under consideration by including the following information:

- Number of VNFs composing the network service.
- Type of packaging employed for the network function. For example, if the service should be packed as a Virtual Machine (VM) or containerized. This will lead to the two families of NetApps within the 5GASP context: VNF or CNF as explained in the next section.
- Maximum tolerated latency in milliseconds.
- Need for connectivity with the Internet.
- Hardware resources required to deploy the service, e.g., CPU cores, RAM, storage requirements, etc.
- Services's delivery model, e.g., if the function is packaged as a VM image or in a docker container and its location.
- Ingress and egress bandwidth requirements of the service.

Besides, during this first design phase, the dependencies with other NetApps should be also identified. This is notably important in the case of implementing inter-working NetApps, which collaborate to meet the requirements of a given vertical use case.

The second step of the design phase addresses the detailed definition of the requirements of the NetApp from the perspective of the 5G infrastructure. Concretely, the programmer should indicate how many network slices are needed as well as their characteristics. This is done by means of a Network Slice Type (NEST) document that is a filled Generic Network Slice Template (GST) as introduced by the GSM Alliance (GSMA). This procedure is currently under development.

Finally, the third stage of this phase is intended to define the set of tests that must be carried out by the 5GASP platform in order to validate the NetApp under evaluation. This permits to avoid errors during its instantiation or operation on the targeted vertical use case. The tests should be described according to the test descriptors that will be developed in further stages of the project.

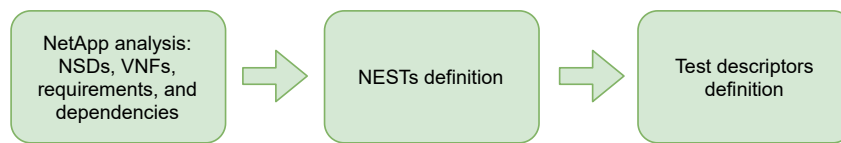


Figure 1: 5GASP NetApp design stages.

2.2 Development

Once the design of the NetApp is performed, the developer can start developing different descriptors that conform the NetApp as a whole. To do this, as shown in Fig. 2, the methodology considers a division of the development phase into three steps: (i) the VNF Descriptors VNFDs/NSDs, (ii) the GST/NEST, and (iii) the test scripts and test VNFs descriptors. The development insights of the NetApp functionality itself, i.e., the code of the application, are out of the scope of this methodology definition.

The first descriptor to take into account is the VNFDs/NSDs that conform the NetApp. These descriptors must follow the standards that will be supported by the NFV Orchestrators (NFVOs) offered by each one of the test sites, e.g., OSM or ONAP. This information is available beforehand to the experimenters in order to avoid problems with the descriptor structure and keywords. Depending on the type of NFVO to be used, the format of the descriptors varies. Moreover, the developer has to take into account the version of the NFVO, as there may be differences between them. For example, the format of a descriptor for OSM Release NINE is not the same that for OSM Release EIGHT (or previous releases), as they implement a new northbound API to be upgraded to the new ETSI SOL006. To prevent the developer from having to be aware of these details, 5GASP offers the specific type and version of the NFVO available on testbeds, as well as examples for them. Furthermore, some examples of descriptors are available to simplify the developer's job, easing the task avoiding their creation from scratch. It could be also possible to offer some "ready-to-fulfil" descriptors, which could be customized by developers (for example, the number of hardware resources, or network interfaces). Also, a list of network and computing resources available on each facility is offered to developers, where they can easily select the resources they want to use in their NetApps.

Secondly, when preparing the GST/NEST descriptor for the NetApp, it is important to take into account the capabilities of the testbeds. A list of predefined NEST for each testbed are offered to the developers when onboarding the NetApp, therefore the network slice assigned to the NetApp in the deployment is of the default network slices. Further on in the project, the experimenter will be also able to select the desired capabilities for the network slice, and a series of available NESTs from the different testbeds will be offered, leaving the decision of which one will be used to the developer. Finally, the 5GASP framework will also accept the NESTs defined by the experimenter, choosing a best-effort option if the requirements demanded by the NetApp cannot be fulfilled by any testbed. As a consequence, it is important for the developer to know the network resources that the NetApp will demand once deployed, in order to achieve an optimal operation and with the aim of passing all the test and validation procedures and obtain the certification by the 5GASP platform.

Finally, regarding the development of the testing descriptors, the approach may change depending on the type of tests. In first place, multiple infrastructure-related tests are pre-provided by the different test facility sites. Thus, the developer can avoid to implement these kind of tests, as they will be available to select during the onboarding process, and they will have the correspondent KPIs associated, in order to be included in the NetApp descriptors. Moving on to the custom test scripts, the code itself is under the responsibility of the developer, and he/she needs to define an output to establish the success or failure of the test.

Regarding the custom test VNFs, the development considerations are similar to the ones presented

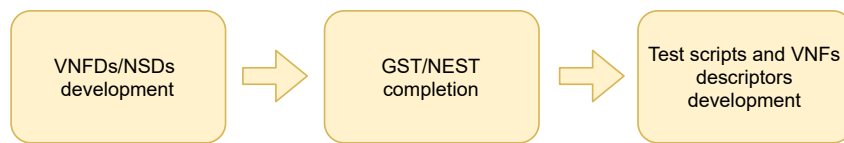


Figure 2: 5GASP NetApp development stages.

and discussed above in relation to the NetApp VNFDs/NSDs. It is important to mention that from the point of view of these test VNFs, the NetApp must be considered as a blackbox with some inputs and some outputs, which are the ones used to validate the test. In this way, these VNFs commonly embed specific applications with a certain configuration prepared to validate a concrete aspect of the deployed NetApp. For example, a testing VNF could be a traffic generator together with a certain data packet trace, in order to evaluate the behaviour and response of the NetApp when that specific traffic is received and processed.

3 NetApp Management

As explained previously, NetApps are understood as a set of virtual functions, which facilitates an automated and repeatable deployment and testing cycle. In order to follow standardized procedures, NetApps should be designed and developed following models proposed by well-known standardization bodies. For that reason, in 5GASP the ETSI's SOL005/OSM (YANG) and SOL001/ONAP (TOSCA) models have been adopted. Consequently, adaptations and enhancements could be made on those models to enable particular deployment and testing scenarios.

Furthermore, the 5GASP platform provides developers with a single entry-point by means of a portal to enable a straightforward procedure towards the onboarding process. This portal allows any developer to onboard the designed NetApp, specify the accommodating testbed to host it, and describe the tests that should be triggered once the NetApp is deployed. This “triplet” is bundled together in a single entity creating an unified abstraction for all sites, thus assuring that the onboarding, activation and testing can be properly performed on any 5GASP facility. Also, with the aim of achieving a full interoperability with any NFV/3GPP-compliant 5G system, the 5GASP's approach for each entity of the “triplet” is to be defined under widely embraced models in the industry, i.e., GSMA's GST/NEST, TMF's ServiceSpecification and ServiceOrder.

Finally, as mentioned above, NetApps can be implemented as ordinary VM-based approaches or as the more contemporary container-based one. Both strategies are supported by the 5GASP platform and present each pro and cons as explained in the following.

3.1 NetApp Categories

Although the NFV precepts are completely agnostic about how VNFs are instantiated, in practice the most common method so far is deploying them as VMs. Nevertheless, in recent years the instantiation of VNFs as containers has become more popular, since its deployment, scaling, etc., is considerably faster and requires lower resources. However, for certain purposes, it may be necessary to use one or the other depending on the characteristics and needs of the NetApp, or even depending on the facility where it is going to be deployed. For that reason, the 5GASP platform support both possibilities transparently to the NetApp developer.

3.1.1 NetApps as VMs

During the last years, deploying VNFs as VMs is the most widely used way to instantiate them. A VM-based VNF is a virtual machine with hardware resources, network interfaces, and essentially, an image (usually qemu-based) that includes/implements the desired functionality. Therefore, one of the most important points when deploying a VM-based VNF is to have the image that conforms the VM, since it is the one that will contain the functionality offered by that VNF. To do this, normally a previously configured image is available with basic functionality (for example, the necessary packages installed),

ready to receive the specific configuration required (IPs, targets, configuration files, etc.) after its instantiation. Thus, it is obtained a generic-enough image to adapt to the characteristics of the scenario, but specific-enough for not having to do all the required configuration after the instantiation process, which reduces the time needed until the VNF is ready.

To automate the image generation, other related projects such as 5GTANGO⁵ have developed methodologies to create VM-based images which consists of selecting a pre-existing docker container (or uploading one) that implements the required functionality. Once identified, it generates a VM with a Vanilla OS, e.g., a freshly installed Ubuntu distribution, and installs the container on it. Then, a new VM image is generated based on that VM, so an image with the required functionality is ready to be instantiated. Another typical option is to use a base image and configure it when deployed using different methods, e.g., Ansible. In this case, a *yaml* file includes the packages and functions to be installed, defining with a template and scripting system, the configuration files to be deployed on the VM to properly configure the VNF. Another possibility to inject configuration is using Day-0 and Day-1 configuration (from OSM) that uses Juju Charms to configure instances [2].

3.1.2 NetApps as Containers

The other approach to build cloud-native 5G NetApps is by means of Containerized Network Functions (CNFs). The principal aim of CNFs is to reduce the weight of VMs, as CNFs consist of a series of micro-services that can be flexibly instantiated in different targeted systems. This approach also provides low-latency and ultra-reliability guarantees, among others advantages.

The motivation for the development of a CNF-based VNF infrastructure is that monolithic network functions implemented as VMs require a long time to be deployed. Thus making VMs much less scalable than CNFs, specially considering specialized container-management tools such as Kubernetes, which also provides monitoring tools for quick and smart CNFs handling. Following this approach, VNFs can be rapidly replaced or moved to different points within the network infrastructure attending to current needs.

Thereby, the reduced footprint of microservices and their fast instantiation and launching times bring a range of advantages in terms of high performance to deal with the requirements of advanced 5G services. This is specially critical in the case of ultra reliable low latency communications (urllc) applications [1].

4 Conclusion

The principal objective of 5GASP is to boost the development of advanced network functions under the umbrella of the 5G ecosystem. To this end, the project is defining a detailed methodology to design and develop this type of in-network services. The proposed approach permits an automated and reproducible validation of NetApps across multiple facility test sites, including inter-domain scenarios. In this line, 5GASP aims at implementing an operational platform to serve as a reference infrastructure for test and deployment of 5G trials. In this paper, the conceptual methodology for designing and developing 5G-oriented NetApps was explored. It allows an agile and safe development of NetApps prior to their testing and certification. Besides, we have also presented the NetApp management process considering the different categories of NetApps, namely, VMs and containers. As future work, during the next project stages, further iterations and enhancements to the methodology will permit to improve automation the automation of the procedures. Besides, we plan to effectively onboard functional NetApps under a specific vertical use case in order to explore the real functioning of the 5GASP platform.

⁵<https://www.5gtango.eu/>

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