5GTANGO: An Approach for Testing NFV Deployments

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***Abstract*—Programmability, control and flexibility can be considered as some of the indirect enablers for the success of 5G technologies. A key driver towards this are mechanisms or methodologies to drive shorter time to market for suppliers and operators of virtual network functions (VNFs) and network services. 5GTANGO includes a DevOps approach that can be utilized for the validation and verification (V&V) of VNFs and network services. In this paper, we elaborate further on the approaches made in the areas of testing, catalogues and package management as a means to enable that full DevOps V&V workflow. Finally, we explore the deployment requirement of the V&V via one of our pilot use cases**

I. Introduction

Network operators look for more agile and faster service development in order to regain the significant market loss from over-the-top (OTT) providers which, so far, have done an excellent job in bypassing and dis-intermediating telcos to provide customer-centric new digital services. Network operators need to re-position themselves and become as agile as OTT digital players. This means looking beyond traditional business models in a changing telecom value network. Network function virtualization (NFV) and software-defined networks (SDN), as drivers for DevOps adoption in the telecom segment, are already seeing traction. For example, OSM [1] and ONAP [2] are beginning to implement aspects of DevOps workflows to support their respective deployments.

Automation of deployment is a key challenge for quick time to market of the new, innovative NFV deployments that are envisioned to support future 5G networks. One of the key aspects of 5GTANGO's effort to support shorter time to market is to address the tooling that enables the closer development and deployment between an equipment vendor or SME development team and the telcos network operations. Validation and verification tooling and associated testing methods for third-party developer services over replicated operational infrastructures allows for the realization of true carrier-grade deployments that ensure reliability. Network service operators need to ensure that the behavior of VNFs and corresponding network services are consistent across multiple different service execution platforms.

The promise of NFV is to relocate network functions from dedicated hardware appliances to software on off-the-shelf hardware. However, incomplete or inconsistent configuration of VNFs and network service forwarding graphs could cause break-down of the supporting infrastructure [3]. In addition, environments (NFV/MEC infrastructures) where the NFV services are being deployed are not homogeneous [4]. It is anticipated that there will be other virtual infrastructure management and virtualisation platforms used NFV infrastructure (NFVI). In this sense, verification and validation of network services and VNFs is critical for network operators to check that their requirements and network properties are correctly implemented in the execution infrastructures.

The main building blocks of the NFV architecture are (i) VNFs; (ii) the NFVI; (iii) the Management and Orchestration (NFV MANO); (iv) the network services. The proposed approach targets mainly (i) and (iv) respectively, however as the pluggable architecture that 5GTANGO supports allows for VNF and network service specific management and orchestration components, it will also tackle (iii). Today the validation and verification of these deployments is typically limited to schema or syntax checks however in 5GTANGO we propose a framework that tackles the verification and validation of the network services and VNFs for all phases of a DevOps cycle. In this context functional and non-functional tests will be offered by the V&V platform, readily available for the developer to select and include into his service package and then execute in a pre-deployment environment. The described architecture is presented in [5].

As the issue of validation is critical, ETSI NFV ISG has released a number of documents giving a framework for pre-deployment validation and testing [6] as well as interoperability and portability [7]. The proposed methodology uses the definition of System Under Test (SUT) in order to categorize test procedures for each unique building block of the infrastructure.Similarly ONAP [2] is creating a validation program to provide assurance of VNF interoperability. In [8] the authors propose a framework for end-to-end service chain performance profiling on different target platforms. Facing the issue of standardised validation and verification test notation and description, ETSI TTCN-3 has developed a test specification language that applies to a variety of application domains and types of testing [9]. The intention is to use TTCN-3

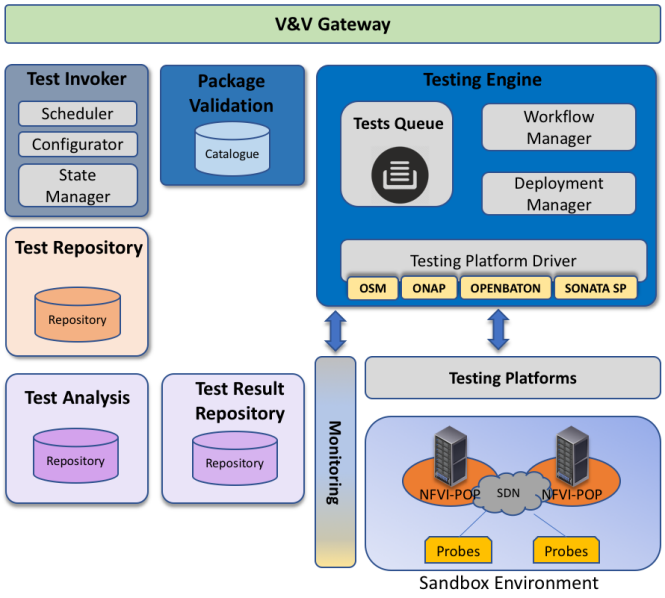

Fig. 1. V&V platform architecture

language an extend it towards NFV validation and verification. This paper is structured as follows. Section III covers the management of tests, including packaging mechanisms. Section IV describes the use of test results. Section V covers catalogue-based features that analytically reduce test results and finally, Section VI is focused on how V&V deployments can be optimized to fit 5GTANGO's pilot requirements.

II. V&V Platform Architecture

This section briefly presents the high level architecture of the V&V platform, which can be seen in Fig. 1. The V&V platform is comprised of the following components: (i) the *V&V Gateway* which is responsible for exposing APIs towards the testers in order to submit packages for validation and verification; (ii) the *Test Invoker*, responsible for the test case configuration, scheduling and maintenance of the test state; (iii) the *Test Repository* which contains the test descriptors for supported test cases; (iv) the *Package Validator* for the validation tests of the submitted packages (i.e., containing a number of descriptors and metadata information); (v) the *Testing Engine*, the component that actually deploys the SUT and via specific driver (i.e., depending from the testing platform required) instantiates the network service/VNF and the required probes; (vi) the *Test Result Repository*, keeps the raw results of the metrics acquired during testing and (vii) the *Test Analysis*, responsible for the results post-processing and the presentation to the tester via the V&V Gateway.

III. Test & Package Management

To control the proper application and execution of groups of tests towards the target network service, tests must be categorized an matched to their corresponding network service targets. Test groupings can be made across many categories but should consider the following areas: *functional*, *performance*, *syntax API*, and *security* testing. We use a tagging approach to implement this categorization and matching feature in 5GTANGO.

A. Test Suite, Test Case and Test Profile

A test plan is a document which outlines the what, when, how, who, etc. of a testing project. It includes the objective and scope of the tests to be run. It serves as the general guideline for a testing project and for developing the test cases.
In 5GTANGO, the test plan is foreseen to be constituted from two parts: 1) from 5GTANGO which defines the generic scope and test objectives to test the compliance of VNF/network service regarding to ETSI-NFV specifications; 2) from the infrastructure provider who defines the test objectives specific to the NFV infrastructure on which the VNF/network service under test is to be deployed. The test plan is then comprised of test cases which implements the test objectives defined in the test plan. A test case is a document which specifies the required test data, the preconditions, test steps, expected results, and postconditions. A test case aims in general to validate one test objective, for example, the HTTP server returns a success code upon a correct message.

A test suite is a collection of test cases to test one specification that the SUT needs to be compliant with. For example, we can have a test suite which verifies the authentication feature of the SUT which can be decomposed to several single test cases to constitute the entire authentication workflow. One test suite usually corresponds to a subset of test cases targeting the features or specifications of one aspect, such as functionality, performance, interface, security. The test profile is defined as a subset of tests from the complete set of mandatory and optional tests that verify all the requirements of a specific type of product.
Let's take an example of a VNF which implements the firewall functionality. We can thus first define a product profile which is "firewall". As a VNF, it needs to be compliant with all the specifications for a generic VNF, and as a firewall, it needs to satisfy the functional and non-functional requirements towards a firewall software component. In 5GTANGO, test profiles are defined by the project regarding the most frequent developed and deployed VNF or network service, such as vSwitch, firewall, or defined by the third party V&V platform provider.

Fig. 2 shows an example of the relationship between test plan, test profile, test suite, and test case. Test profiles, test suites and test cases are developed according to the test plan(s) The test profile "vSwitch" includes two test suites which have different test objectives, and the test profile "firewall" includes also two test suites. The test suite "Ve-Vnfm" belongs to both profiles. Test cases are chosen to be included in each of the test suite in order to accomplish the the objective of the test suite

B. Package-based Workflow

Once, a developer has created a VNF or network service, it has to be tested and validated by the proposed V&V frame-

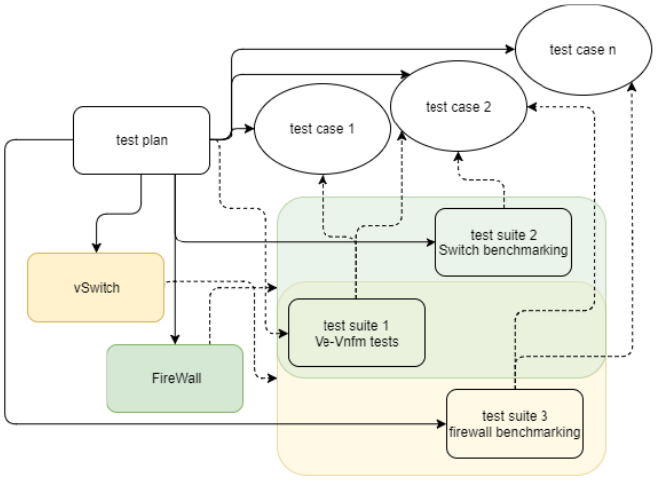

Fig. 2. Test plan, test profile, test suite and test case

work and finally be uploaded to the target service platform that deploys the production instance of the service. In this workflow, VNFs, network services, test definitions, and test results need to be exchanged between different parties, e.g., developers, V&V providers, and service platform operators in a flexible and trusted way. To achieve this, 5GTANGO uses *packages* as first class exchange artifacts and introduces an advanced packaging format that goes beyond existing cloud and NFV packaging concepts [10], [11] but still is fully backwards compatible to ETSI's VNF package format [10]. 5GTANGO packages can either contain VNFs, entire network services, test definitions, test results, or a combination of these [12].

To enable the proposed V&V concepts, two additional features were introduced in 5GTANGO's package specification [12]. First, all packages are immutable and always signed by the entity which created them. For example, a network service package P_N is signed with the developer's private key s_k when the service is packaged $\hat{P}_N = S(P_N, s_k)$. Using the developer's public key p_k, a V&V provider or a service platform operator can always verify that a package was created by the developer and has not been changed ($V(\hat{P}_N, p_k) = 1$). Second, 5GTANGO packages allow to reference other 5GTANGO packages using a globally unique identifier and a checksum to ensure the integrity of the referenced package. By combining these two features, the full package-based V&V workflow is enabled: The developer creates and signs a network service package $\hat{P}_N$, submits it to a V&V provider for verification, and receives a test result package $\hat{P}_T$. The test result package is signed by the V&V provider and references the corresponding network service package, i.e., $\hat{P}_T \xrightarrow{\text{ref.}} \hat{P}_N$. These two packages can now be submitted to any target service platform to deploy the operational service instance. The package signatures ensure their integrity such that a platform operator can easily decide which packages to accept (e.g., verified by a trusted V&V).

5GTANGO's package-based test and verification concept enables new business models, in which service platform operators certify certain trusted V&V operators which can then be used by developers to test and verify their VNFs and network services.

C. Test Requirements

Each test comes with a test descriptor that includes relevant information for test preparation and execution, e.g., allowing categorization of tests like latency, throughput, or functional tests. Similarly, descriptors of network services and VNFs can include testing tags, specifying different types of applicable tests. This allows the V&V to automatically select suitable tests and enables sophisticated scheduling mechanisms for each kind of test.

To ease the descriptor creation, 5GTANGO offers tools for automatic descriptor generation that allow developers to specify relevant high-level information in a simple, graphical interface. Developers can then generate complete descriptors with a single click, which are are generated using the provided information and combining it with sensible default values. In doing so, manual steps are minimized and simplified such that the whole process is streamlined, accelerated, and less error-prone.

D. Test Environment Preparation and Test Execution

In the V&V multiple test requests may arrive at the Test Engine, those requests are queued in order to be executed in sequence. For each test at the top of the queue, a network service is related to it (based on the information included in the initial package submission. The first action from the Test Engine is to request the deployment of the network service to be tested via the appropriate test Service Platform (SP). Although the main SP that will be supported is the one that 5GTANGO will develop, other SPs such as OSM and ONAP are considered. As soon as the network service is deployed the Test Engine will deploy the appropriate probes in the Sandbox environment and configure the environment in order to steer the test traffic through the service graph. Our approach will cover both hardware based probes (i.e., traffic generators) as well as virtualised probes (i.e., vms running opensource measurement tools such as iperf, owamp etc). When the test probes are deployed and configured, the test scenario will be executed. During execution various monitoring flows and telemetry data are generated from all possible sources beyond the deployed probes, namely the VIM, the transport network (i.e., NMS) and the Service Platform itself. The monitoring system is capable of collecting all this information separately for later assessment.

IV. Test Result Management

The objective of V&V platform is to provide comprehensive data sets on the tests executed on the SUT rather than to provide a conclusion on whether the SUT has good/poor performance or whether the SUT can be deployed on the target infrastructure. All the test data will be presented in

a machine-readable format (i.e., XML, JSON, YAML) for further processing by other 5GTANGO modules.

However, the amount of raw test data is so vast for a human being, e.g., the developer, it would be preferred to have high level information that can be quickly viewed and provides a approximation of the SUT's quality, after all the tests have executed. For this purpose, a star system is proposed to abstract the V&V raw test results. The principle of such abstraction is to score the SUT according to multiple test results and to map the score to a pre-defined classification offering a general qualification of the SUT. For example, a SUT that successfully passed 90% of all the functional tests will be annotated with five stars. To put forward such a star system, two specifications are essential: 1. The scoring rules specify which test contributes how many points in the total score; 2. A classification of the quality rating of the SUT regarding to the obtained score.

The final number of stars will not replace the raw test data to be submitted to the catalogue for metadata annotation. It is an approximative abstraction for users.

V. Catalogue Management

One of the several key components that constitute the V&V platform is the 5GTANGO catalogue. The aim of the catalogue is the provision of a multifaceted repository, among with some enhanced functionalities with the aim to support different stakeholders needs with continuous adaptive optimization techniques. The catalogue will serve developers via functions for storing, searching and retrieving VNFs and network services, annotating them with additional representation (as metadata). In addition, the operators of the infrastructure will be provided with a mechanism that will enable the automated analysis of the information relevant to VNFs/network services and their validation. Thus, while incorporating fundamental functions of the V&V platform, it offers persistent storage and monitoring feedback of the element under test. Additionally, going beyond a metadata-enriched store, the 5GTANGO catalogue presents two added automated mechanisms, namely decision support and continuous optimization.

The role of metadata is of paramount significance in 5GTANGO catalogues functionality, rendering it an information-driven repository. The information of all stored objects allows the efficient search, correlation between inputs from several 5GTANGO components, versioning, updates etc. The V&V outcomes (i.e., test results), the profiling outcomes, the policy rules and the service level agreements (SLAs) from the service platform, the licensing information from the service development kit (SDK) and the descriptors of the stored VNFs/network service comprise the metadata and serve as a valuable feedback information to the catalogue. The interaction of the catalogue with several 5GTANGO components (such as the V&V platform and the SDK) offers the key advantage of being fully metadata and deployment pattern aware.

Decision support: The goal of the decision support mechanism is to grant optimum combinations of VNFs/network services selection from the overwhelming plethora of existing services. In pursuance of matching the needs of the developer while exploiting the assets of the stored services, the filtering and the prioritizing of the metadata is a necessity for the proposed decision-making process. In terms of analyzing the stored metadata, the suggestion of the service is significantly dependent on the Quality of Service (QoS) and Quality of Experience (QoE) requirements of the infrastructures operator. The aggregation of the stored information allows a mechanism to implement state-of-the-art recommendation system techniques, such as collaborative filtering [13] to build on QoS predictions.

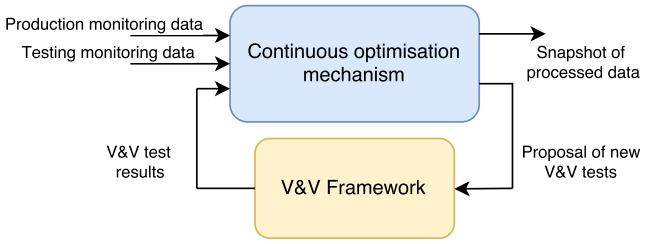

Fig. 3. Continuous optimization mechanism of the catalogue

Continuous optimization: The continuous optimization mechanism is an adaptability feature for the V&V platform. The monitoring feedback information from the actual deployed VNFs/network services in the production infrastructure, enable the proposition of new advanced V&V tests for optimized operations, during deployment and runtime,furthermore, the proposal of new V&V tests takes into consideration the results of the applied test scenarios. The recommendations of the new tests are transferred to the V&V framework to be executed, while simultaneously presented to the developer in order to inspect the efficiency of the services. Furthermore, the metadata of the 5GTANGO catalogue will be updated with the new test results along with information from runtime monitoring, utilizing a "feedback loop" between the catalogue and V&V framework (Fig. 3).

VI. Deployments of the V&V (V&V Ecosystems)

The 5GTANGO system will be demonstrated in three vertical pilots. One of these pilots, named Smart Manufacturing will be realized by Weidmüller Group in Detmold, Germany. The pilot demonstrates among other things the application of SDN and NFV in the industry sector by using the 5GTANGO system. It is applied in the context of machine-to-machine (M2M) communication, in which industrial field bus systems are initially behind the scope of this pilot; nevertheless, its application is part of further research and development. This concept can accelerate the evolution of industry 4.0 because machine networks become more flexible and scalable; i.e., networks can be flexibly adjusted to the individual needs of Industrial Internet of Things (IIoT) applications that use these networks.

The pilot is focused on processing and analysis of operational, machine and process data (O/M/P data) generated by the machinery present in the manufacturing site. Data will be used for manufacturing process optimization by using synergies and correlations between data from different machines, but online optimization needs real-time interaction and low latency. Therefore, latency must be minimized, but data transfer across the internet can cause high latency. For this purpose, local instances of the 5GTANGO system are necessary near the machines. The pilot is described in more detail in [14] and the architecture of the software platform to be created in the 5GTANGO project is described in [15].

Considering the overall 5GTANGO architecture described in [15], at least a local instance of the 5GTANGO service platform is necessary, so that VNFs and network services can be locally deployed for operating with machine interaction with low latency.

The 5GTANGO service development kit is necessary for local development and a local 5GTANGO V&V platform is useful for testing on the infrastructure which will be used, but a local public catalogue is not necessary. However, one V&V instance could also be used by different operators if both operators use the same infrastructure. Nevertheless, local deployment is necessary to guarantee low latency.

VII. CONCLUSIONS

The testing approach and innovations presented in this paper elaborate on some of the mechanisms that are used to develop an effective DevOps test workflow. By delivering a test management system supported by a signed package workflow both operators and developers can be assured that their VNFs and network services are from trusted sources, while still having the flexibility of ease of transfer between differing deployments. Equally both the catalogue and corresponding test results systems offer ways of reducing the complexity of analysing the test results allowing as an example, quick decisions on the re-use of services or VNFs when creating new service offerings.

We also present how our pilots intend to deploy the V&V where specific requirements such as low latency can be addressed by distributing the V&V deployments while also allowing for sharing via a repository like ecosystem. We believe that these approaches show effective mechanisms for the delivery of a highly competitive test workflow that can be utilized as a part of the V&V lifecycle towards any of the current MANO stacks.

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REFERENCES

[1] OSM Members, *OSM Opensource Project*, ETSI, Ed., 2018. [Online]. Available: osm . etsi . org/ (visited on 02/06/2018).

[2] ONAP Consortium, *ONAP Opensource Project*, L. Foundation, Ed., 2018. [Online]. Available: www.onap.org (visited on 02/06/2018).

[3] M.-K. Shin *et al.*, "Verification of nfv services: Problem statement and challenges," IETF Secretariat, Internet-Draft draft-irtf-nfvrg-service-verification-05, Oct. 2017.

[4] *Openstack*, 2018. [Online]. Available: www.openstack.org (visited on 02/06/2018).

[5] M. Zhao *et al.*, "Verification and validation framework for 5g network services and apps," in *IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN)*, Nov. 2017, pp. 321–326.

[6] ETSI, *Pre-deployment Testing; Report on Validation of NFV Environments and Services*, ETSI Industry Specification Group (ISG), Ed., 2016. [Online]. Available: www.etsi.org/deliver/etsi_gs/NFV-TST/001_099/001/01.01.01_60/gs_NFV-TST001v010101p.pdf.

[7] ——, *Testing Methodology; Report on NFV Interoperability Testing Methodology*, ETSI Industry Specification Group (ISG), Ed., 2016. [Online]. Available: www.etsi.org/deliver/etsi_gs/NFV-TST/001_099/002/01.01.01_60/gs_nfv-tst002v010101p.pdf.

[8] M. Peuster and H. Karl, "Profile Your Chains, Not Functions: Automated Network Service Profiling in DevOps Environments," in *IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN)*, Nov. 2017.

[9] ETSI, *TCCN-3 Standards and Specifications*, Centre for Testing and Interoperability (CTI), Ed., 2018. [Online]. Available: www . ttcn - 3 . org / index . php / downloads / standards.

[10] ——, *ETSI GS NFV-SOL 004: VNF Package specification*, ETSI Industry Specification Group (ISG), Ed., 2017. [Online]. Available: www.etsi.org/deliver/etsi_gs/NFV - SOL / 001_099 / 004 / 02 . 03 . 01_60 / gs_NFV - SOL004v020301p.pdf (visited on 02/01/2018).

[11] Standard, OASIS, *Topology and orchestration specification for cloud applications version 1.0*, 2013. [Online]. Available: docs . oasis - open . org / tosca / TOSCA / v1 . 0 / TOSCA-v1.0.html (visited on 02/01/2018).

[12] 5GTANGO Project, *5GTANGO Package Specification*, M. Peuster and S. Schneider, Eds., Jan. 2018. [Online]. Available: github . com / sonata - nfv / tng - schema / wiki / PkgSpec_LATEST (visited on 02/01/2018).

[13] B. Sarwar *et al.*, "Item-based collaborative filtering recommendation algorithms," in *International conference on World Wide Web*, ACM, 2001, pp. 285–295.

[14] 5GTANGO Project, *D2.1 Pilot Definition and Requirements*, R. Muñoz and R. Vilalta, Eds., Sep. 2017. [Online]. Available: 5gtango.eu/documents/D21_v1.pdf (visited on 01/26/2018).

[15] ——, *D2.2 Architecture Design*, M. Peuster and S. Schneider, Eds., Nov. 2017. [Online]. Available: 5gtango . eu / documents / D22_v1 . pdf (visited on 01/26/2018).