ARCADIA

A novel reconfigurable by design highly distributed applications development paradigm over programmable infrastructure

Deliverable D6.11

Scientific Workshop Report V1

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0.1	23/06/2016	M. Repetto (CNIT)	Document template, TOC
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1.0	28/07/2016	M. Repetto (CNIT)	Changed according to internal review

Executive Summary

This deliverable provides a report from the first ARCADIA workshop, held in Athens during EuCNC 2016. The workshop gave insights on the ARCADIA architecture, on-going work, prototype implementation, and established connections with other related initiatives.

The workshop included presentation of the ARCADIA project, presentations from the industry, and presentations from other EU projects. Following the invited speeches, a panel was organized to discuss the relevance of the ARCADIA framework to the evolving cloud landscape, to highlight novel trends that have emerged after the project proposal, to reinforce collaboration with parallel EU projects, and to gather suggestions, ideas, remarks in order to improve the project. To this aim, members of the Advisory Board were invited to attend the workshop.

This document briefly summarizes the main content of the invited speeches and the main topics discussed during the panel. It also summarizes the main directions and suggestions that emerged during the discussion.

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1 Introduction

1.1 Scope

As part of its dissemination strategy, ARCADIA planned to organize three scientific workshops, targeted to the scientific and industrial communities in the domains of software development, cloud computing, and virtualization [1].

This report documents the 1st ARCADIA workshop, planned for presenting the project's intermediate result, namely the definition of the ARCADIA Context Model and the design and specification of the ARCADIA Framework.

1.2 Audience

This deliverable is intended for public dissemination (including the Commission Services).

1.3 Structure

The document is structured as follows:

- Section 1 introduces the deliverable, its scope, and its structure.
- Section 2 provides a quick factsheet of the workshop.
- Section 3 explains the main objectives for this workshop and the overall strategy behind its organization.
- Section **Error! Reference source not found.** reports a brief summary of the speeches and final discussion.
- Section 6 gives the conclusions.

2 Workshop factsheet

Title	ARCADIA Special Session on Software engineering approaches aligned with the Softwarization of Networks and Services
Event	European Conference on Networks and Communications (EuCNC 2016) http://www.eucnc.eu Athens, Greece, June 27-30, 2016
Venue	Divani Apollon Palace & Thalasso, Room Kleoniki B Agiou Nikolaou 10, Vouliagmeni, Athens 166 71, Greece
Date	Wednesday, 29 June 2016, 11:00-12:30
Chair	Raffaele Bolla (CNIT, Italy)
Participants	40 participants attended the workshop, including people from the industry (telcos, vendors), people from SMEs active in the 5G domain, as well as people from the academia and research institutes.
Programme	11:00-11:20 “Network softwarization”, Antonio Manzalini (TIM) 11:20-11:40 “NFV and SDN interplay and orchestration challenges”, Pedro A. Aranda Gutiérrez (TELEFONICA I+D) 11:40-11:55 “The ARCADIA Framework: a complete framework for software development, orchestration, deployment, and execution”, Anastasios Zafeiropoulos (UBITECH) 11:55-12:10 “Bringing computing at the network edge for virtualization of devices and things: the INPUT infrastructure for fog computing”, Roberto Bruschi (CNIT) 12:10-12:30 Panel: “Deploying distributed applications over next-generation programmable infrastructure: vision, challenges and research directions”, moderated by Dr. Nikos Koutsouris (WINGS), Dr. Antonio Manzalini (TELECOM ITALIA), Dr. Roberto Bruschi (CNIT).

3 Objectives and motivations

3.1 Objectives

The 1st ARCADIA workshop was conceived for presenting the project's intermediate results after the first year of activity, and to gather feedbacks, interests, suggestions from the community.

3.2 Motivations

The first year of activity in ARCADIA was mainly devoted to framework specifications, including the identification of relevant use cases, the collection of requirements, the outlining of the overarching ARCADIA framework (software development paradigm and orchestration environment), the preliminary definition of the Context Model for developing and deploying ARCADIA-compliant applications. All these activities were carried out in Work Package 2 (WP2) and documented by the relative deliverables[1].

The work undertaken during the first year was specifically focused to blur the demarcation line between infrastructure and software development, by understanding how the emerging programmability of cloud environments could be reflected and exploited by programmers in order to make their applications "ductile", namely adaptable to mutable execution environments and conditions. In this respect, the idea beyond the first workshop was to foster the discussion about the synergy between novel software development paradigms and the increasing levels of infrastructure programmability; in particular, ARCADIA envisions a still largely unexplored potential of network programmability in the implementation and deployment of complex software ecosystem, including the concept of Software-Defined Networking (SDN).

Given the above considerations, the Project decided to present the ARCADIA vision and preliminary results in a networking/communication context, deferring the debate with the software development community to the following workshops, when more focused technical achievements would have been available for discussion.

3.3 Scope

The grow of Internet-centric paradigms (like the Internet of Services, the Internet of Things) is boosting the need for more distributed and modularized applications. New computing architectures are emerging to tackle these paradigms, like cloud federations and "*fog*" computing. This evolution brings a new dimension to the software development process, which shall take into account the prominent role of networking and its implications for distributed systems (QoS, security, dependability, ...) as well as the increasing trend towards the softwarization of networks and services.

Given the heterogeneity of the computing and networking solutions, it is vital to introduce novel software development paradigms that facilitate the automatic deployment and reconfiguration of the applications over distributed infrastructures, by taking advantage of the increasing programmability of such underlying infrastructures. To this aim, principles and techniques already available in recent software engineering paradigms shall also consider ground-breaking concepts in the networking domain, like Network Function Virtualization (NFV) and Software Defined Networking (SDN).

[1] Public deliverables are available on the ARCADIA website. URL: http://www.arcadia-framework.eu/wp/documentation/deliverables/.

The intention of the workshop was to gather prominent experts from both academic and industry and promote an open discussion on the development of *Reconfigurable-by-design* applications, fostering a tighter collaboration between the Software Development, the Computing and the Networking domains.

The workshop provided an overview of on-going work in the EU projects ARCADIA and INPUT, and presentation of related initiatives in the SDN/NFV domain. The main goal was to share bleeding-edge knowledge, to cluster complementary activities, and to stimulate the synergy and cooperation from different technology domains and research project.

3.4 Organization

Given the motivation outlined in Section 3.2, the workshop was organized to foster the discussion with relevant experts and parallel initiatives from the networking domain. Key topics for the discussion were cutting-edge technologies in this field, namely Network Function Virtualization (NFV) and Software-Defined Networking. Invited speakers were selected in order to depict a clear and authoritative vision about the main trends in the industry and in the research community. Further, a representative from the Advisory Board was highly recommended.

The following people were invited for a speech:

- Dr. **Antonio Manzalini**, Innovation/Future Centre at TIM (Italy). His interests include innovative networking technologies and architectures, network virtualization, 5G, pervasive robotics, Internet of Things. He is strongly involved in SDN standardization.
- Dr. **Diego R. R. Lopez**, Senior Technology Expert, Telefonica I+D (Spain). He is responsible for the definition and coordination of research projects in the areas of new networking technologies and network infrastructures. He is currently Chair of the ETSI NFV Technical Steering Committee, Co-chair of the NFVRG. Dr. Lopez was replaced by Dr. **Pedro A. Aranda Gutiérrez**, Technology Exploration, Network Innovation & Virtualisation, Telefonica I+D. He is the coordinator of the NetIde project.
- Dr. **Roberto Bruschi**, Research Scientist at CNIT (Italy). He is the Project Coordinator of INPUT, an H2020 research project targeting novel virtualization paradigms at the network edge.

Dr. Antonio Manzalini is also a member of the ARCADIA Advisory Board.

4 Workshop summary

This Section reports a brief summary from each speech. It is not intended to be a mere copy of the presentations, rather to extrapolate the key messages and to bring them to the attention of the project Consortium and all interested readers.

The full presentations are available on the ARCADIA websites (only for Consortium members and the EC).

4.1 Welcome and introduction

Prof. Raffaele Bolla, chair of the workshop, gave an initial introduction to the main scope of the workshop, as well as the program that is going to be followed.

4.2 Network softwarization

SPEAKER: Antonio Manzalini, TIM

Networks are undergoing an unprecedented techno-economic transformation driven by the ever growing deployment of IT equipment within communication infrastructures, with the prime aim to realize most legacy functions in software. This trend will ultimately deploy a large amount of computing and storage resources into the network, building a vast programmable execution environment that open the opportunities for far more services beyond mere voice/data transport (5G networks). Telecoms are carefully looking at this evolution, because of the higher revenue margins for value-added services over their traditional business model.

The key driver in this evolution is the definition of some kind of middleware that is able to run heterogeneous services on heterogeneous and distributed hardware, in a transparent, seamless and automated way. This middleware can be designed in a similar way to a modern operating system, offering standardized interfaces to applications and services (similar to system calls and libraries), abstracting the resource diversity (through some abstraction similar to device drivers). The Network Operating System (NOS) should provide a platform for automated operation, bringing together communication infrastructures, IT equipment, terminals. The definition of a NOS entails several on-going initiatives, including the Everything-as-a-Service (XaaS) unification paradigm, service interfacing and templates (e.g., IETF intent framework, OASIS TOSCA/YANG), virtualization environments (e.g., OpenStack, NFV, ONOS), programming and configuration protocols (OpenFlow, Netconf, …), commoditization of Telco central office and disaggregation into edge/fog components (Telecom Infra Project, Open Compute, Mobile Edge Computing, etc.).

The topic has been discussed for several years, and there are many components that could be assembled together in a common architecture (e.g., CORD[2]). However, such a distributed and heterogeneous environment will be characterized by a higher level of complexity than today, and this will be a challenging issue for proper automated control and management.

Artificial Intelligence (AI) may be the right solution for complexity. AI has been already used successfully for detection of cyber-attacks, and its usage is under investigation in different sectors: car driving, smart ambient, financial and market prediction, genetics and DNA programming. But the challenging question is: could AI be the "*end of code*"? May we envision a new paradigm, i.e., AI-defined network for making large-infrastructures and big-data "actionable"?

4.3 NFV and SDN interplay and orchestration challenges

SPEAKER: Pedro A. Aranda Gutiérrez, TELEFONICA I+D

NFV and SDN are promising technologies for networking. However, their real potential is currently overlooked. As a matter of fact, many traditional networking guys are prone to see Network Functions as the "open" version of their legacy middle-boxes and the SDN controller as the delightful replacement of their patch panels. NFV/SDN bring far more opportunities than deploying network services while comfortably sitting at the own desk!

The fine-grained control over packet forwarding enabled by SDN is very useful to optimize service graphs in NFV and to compose applications and services. NFV strongly relies on the concept of recursive composition, starting from elementary software components, to VNFs and Network Services. The notion of application composition goes farer than mere service chaining, envisioning the possibility to perform in parallel several tasks (e.g., firewalling, natting, monitoring), to assemble the result and to apply it to the packet.

From another perspective, SDN is enabling DevOps development cycles which benefit from prior experiences in software development, such as Agile development. The standard software cyclic lifecycle made of design, implementation, test, deployment could be easily adopted for network services and applications, with great benefits in terms of release times and development costs.

Finally, another issue in NFV/SDN converge concerns packaging. NFV is already defining its packaging formats (e.g., OpenMANO, TOSCA), while SDN applications are usually shipped in the controller-specific format (e.g., jar file, python script). There is still a missing gap in bringing these technologies together and converging to a common and overarching standard.

Going further, the last remark is for current description languages. For example, current way of describing Service Graphs in NFV-MANO is human-readable, but.. is it human-understandable? "Intent" is the magic word in this context; it indicates the possibility to specify *what* is expected from the network, rather than *how* to configure the underlying infrastructure. Current efforts in such direction are still at the early stage, and with several drawbacks (e.g., FlowObjectives, Boulder, NEMO).

The final message is a warning to avoid being "seduced" by the buzz recurrent words in NFV/SDN: these are very powerful concepts, though the implementation of their full potential is very challenging and many aspects still need investigation.

[2] Central Office Re-architected as a Datacenter (CORD), Open Networking Lab in collaboration with AT&T. [Online] Available: http://onrc.stanford.edu/protected%20files/PDF/ONRC-CORD-Larry.pdf.

4.4 The ARCADIA Framework: a complete framework for software development, orchestration, deployment, and execution

SPEAKER: Anastasios Zafeiropoulos, UBITECH

The ARCADIA project is targeting the alignment of software development paradigms with the opportunities offered by programmable infrastructure, in order to enable applications and services to dynamically adapt to the current execution environment. The main goal is a tight integration between the development and operations processes, enabling automatic deployment and life-cycle management through integrated annotations into the applications.

The ARCADIA development paradigm aims at building reactive systems by including more context-awareness in applications and services; the approach is based on the modularization, the organization in micro-services and the delegation of the control and management logic to an external entity, namely the orchestrator. The main driver underpinning the project approach is the availability of programmable infrastructures, including both cloud installations and communication systems; in this respect, ARCADIA is explicitly taking into considerations emerging technologies like SDN and NFV.

The ARCADIA framework is an overarching systems encompassing both software development, deployment, and runtime management. Software development is based on two main elements: the micro-services architecture (which allows flexible composition of applications and services) and a Context Model (which allows the specification of relationships, policies, requirements, constraints, performance metrics, etc). The deployment and runtime management system is based on a smart orchestrator which deploys

applications over multiple IaaS, by interpreting the Context Model and by adapting applications/services to the current execution environment.

ARCADIA is currently developing several artefacts to build its framework: a web IDE for inserting annotations into applications and building service graphs, a software repository for ARCADIA-compliant components and service graphs, a policy specification and enforcement framework, an optimization algorithm for distributing software components over multiple IaaS, resource management and overlay networking.

ARCADIA is particularly interested in SDN/NFV. On the one side, SDN enables the programmatic network control necessary to deploy highly-distributed applications; on the other side, Virtual Network Functions are useful to be integrated into complex applications and services (e.g., load balancers, firewalls, etc.).

4.5 Bringing computing at the network edge for virtualization of devices and things: the INPUT infrastructure for fog computing

SPEAKER: Roberto Bruschi, CNIT

The INPUT project is targeting fog computing paradigms by exploiting ICT installation at the Telcos' network edge. The main motivation is the increasing virtualization trend, with an ever larger number of applications and services moved to the cloud, and the difficulty to meet stringent QoS constraints for interactive and multimedia applications. As a matter of fact, latency and bandwidth are key factors for applications like voice and video services, on-line gaming, grid protection, trading, remote control.

INPUT focuses on a specific use case, namely the creation of personal network services. Following the trend to move applications to the cloud, even traditional home devices could be (at least partially) virtualized, leaving only simpler hardware at home. Several reasons motivate this approach: more computation/storage resources available, more flexibility in upgrading the application, less energy consumption at home. In this respect, this Use Case represents an evolution of the Home Gateway virtualization already envisioned by telecoms and the ETSI NFV framework. The Personal Network is a very challenging service, since the end user must have the feeling his devices are still functioning locally, with negligible latency.

To implement Personal Network services, INPUT is defining an execution environment at the network edge. The execution environment provides virtualization capabilities (both as IaaS and PaaS) in order to run Service_Apps, and exploits in-network programmability (through SDN/NFV) to create the correct resource slicing. The main INPUT feature is the capability to follow the user, by moving his Service_Apps close to his current point of attachment to the network. The INPUT orchestrator is responsible to decide which applications should move, in order to avoid bandwidth wasting.

As part of the project activities, INPUT is developing OpenVolcano, a complete virtualization framework including the capability of providing virtual computing, storage and networking, a high-performance virtual switch based on DPDK, and an SDN controller.

Two challenging use cases have already been identified to demonstrate the INPUT framework. The first concerns IoT: simple sensors are deployed at home, while their management/processing software is deployed as virtual instance at the network edge and data are stored in a legacy cloud. The second concerns the virtualization of set-top-boxes: video is decoded at the network edge and the stream is directly sent to network-attached TVs. In both cases the purpose is to show how the INPUT framework enables service providers to design their (Personal Network) services, to deploy the service for each users, and to achieve very low-latency performance.

4.6 Panel discussion

Following the main opinions and works presented in the previous sessions, a short discussion session took into consideration the critical issues still to be tackled, and identified some expected contributions by the industrial and scientific community.

The main aspects emerged from the discussion are briefly described in the following.

4.6.1 Design of SDN/NFV solutions

There has been a great effort in understanding and developing the concepts of Software-Defined Networking and Network Function Virtualization in recent years. Many initiatives have been undertaken both in standardization fora, international research projects, and early industrial and commercial prototyping. Such broad range of interests and initiatives have led to many different architectural approaches and technical solutions, reflective the heterogeneity in scope, background and objectives.

To move from concept to real-world products and services, it is now necessary to find a large consensus towards common and shared architectures, interfaces, protocols, and methodologies, in order to design interoperable solutions that nourish the large ecosystem expected. In this respect, standardization plays a key role, and all stakeholders are requested to contribute.

Among others, EU projects are carrying out a great work on architectures, prototyping, service definitions in this field, but often they do not put enough emphasis on standardization. More effort in standardization is expected from EU projects, in order to capitalize their work, to achieve wide consensus, and to boost the convergence towards common and interoperable technologies and systems.

Several NFV frameworks have been designed with their own internal APIs and interfaces, but the common belief is that none of them will prevail on the others, and the upcoming industrial solutions will be an open

ecosystem made of interoperable components coming from different initiatives. In this respects, common open APIs (southbound, northbound, peer interfaces) are expected for management of network functions, service orchestration as well as support of automated deployment and orchestration of distributed applications.

With the large plethora of different solutions available, it will be crucial to compare them in a standard and uniform way, in order to select the best approaches and to foster convergence among the most promising directions.

4.6.2 Energy efficiency in 5G infrastructures

ICT infrastructures are requested to lower their power consumption for long term sustainability. In recent years, several studies have demonstrated that a large share of power consumption is ascribable to low efficiency in the way networking systems are operated. Re-design of networking components and low-power hardware helps in cutting down energy, but it is clear since several years that the most effective power reduction would only come with global strategies that coordinate the whole system.

SDN and NFV are moving towards new networking paradigms and are expected to bring a tight convergence with computing infrastructures. As a matter of fact, ever more IT equipment is being deployed in network infrastructure, and the virtualization trend is blurring the boundary between the networking and the IT worlds. In this situation, the challenge is a better integration between network and data centres, including peripheral installations at the very edge of the network. There must be a trade-off between performance (in terms of QoS, reliability, availability, dependability) and the power consumed by the infrastructure. The softwarization trend, which decouples applications from the underlying hardware, provides a great flexibility for workload consolidation and efficient hardware usage, but also brings additional complexity in understanding the power consumption and the energy efficiency of software instances.

5G infrastructures are explicitly asked to face the above challenge, and to find sustainable and effective solutions for an ever increasing connected word.

5 Main outcomes from the workshop

Summing up the main topics outlines by presentations and the discussed in the panel, the following main issues have been identified:

- **Issue 1**. There is a need for the harmonization of the "chaos" that exists in the design and development of various SDN and NFV solutions, including the set of service/network functions orchestration approaches.
- **Issue 2**. There is a need for contributions in the relevant standardization bodies on behalf of the EU projects, as well as collaboration among the standardization bodies for production of common specifications.
- **Issue 3**. There is a need for the design and development of open APIs (southbound, northbound, peer interfaces) for management of network functions, service orchestration as well as support of automated deployment and orchestration of distributed applications.
- **Issue 4**. There is a need for common benchmarking methodologies and set of key performance indicators in order to have comparable performance evaluation results and identify advantages and disadvantages per approach.
- **Issue 5**. There is a need for the design and deployment of mechanisms that can support in a holistic way energy efficiency in 5G infrastructures. The cost in terms of energy consumption of the softwarization of the Internet has to be examined.

Consequently, a list of suggested actions to be undertaken or strengthened by the ARCADIA Consortium in the next months have been derived:

> **Action 1 – Insist on standardization**. The Consortium is encouraged to continue its effort in standardization bodies.

Currently, some representatives from ARCADIA are already taken part into the following initiatives:

- the Technical Committee on OASIS Topology and Orchestration Specification for Cloud Application (TOSCA)[3];
- the ETSI Environmental Engineering committee (TC EE), part of the Energy Efficiency technology cluster[4].

More effort is expected to align the ARCADIA software framework to parallel initiatives and projects, in order to identify common interfaces for service orchestration and automated deployment of applications. The ARCADIA framework should also target the NVF environment, as a particular Use Case for service orchestration and deployment.

> **Action 2 – Common benchmarking**. The Consortium is encouraged to define evaluation metrics for its Use Case demonstrators in compliance with other projects/initiatives.

The main objective is to produce evaluation results that can be easily compared with those produces by other solutions and architectures.

[3] https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=tosca
[4] http://www.etsi.org/technologies-clusters/technologies/energy-efficiency

Action 3 – Energy efficiency. The Consortium is encouraged to take into consideration energy efficiency.

Energy efficiency for software deployment is already included in ARCADIA Use Cases. The specific objective for the project is to participate in the emerging discussion of energy efficiency for software, which could provide an energy-aware characterization for applications and their components.

6 Conclusions

The 1st ARCADIA workshop was a great opportunity for the Consortium to meet experts from the SDN/NFV fields. From invited speeches and the final short discussion, it was clear that SDN and NFV are still evolving, and no prevailing architectures and solutions have clearly emerged yet. Upcoming networking infrastructures will be very complex system to manage, and the availability of automatic mechanisms for service deployment and lifecycle management is an inescapable need. This basically confirms the worth of the ARCADIA approach, and also motivates to design quite general solutions, not still tailored to any existing framework.

From the 1st ARCADIA workshop, the Project has earned a general approval about its architecture and the relevance for the NFV use case. However, the Consortium has also received a clear indication that much effort is expected in standardization and harmonization with other undergoing initiatives. ARCADIA is already participating in standardization initiatives, both in the field of software orchestration and energy efficiency. However, the definition of common interfaces and interoperability issues should be explicitly taken into account. In addition, the Project should also consider the definition of common benchmarking metrics to produce evaluation results that are easily comparable with other architectures.

The ARCADIA Consortium is therefore mainly committed to propose/adopt open interfaces in its framework, and to take part into relevant standardization fora. The objective is to improve the current architecture and prototype implementation before the next workshop.

The following two workshops envisioned for the second and third years of activity will target the software development community. In such events, the ARCADIA framework will be presented to get preliminary feedback (2nd workshop), then improved and evaluated in the three project Use Cases (3rd workshop).

Annex I: References

[1] A novel reconfigurable-by-design Highly Distributed Applications development paradigm over programmable infrastructure (ARCADIA). EU H2020 Programme, Grant Agreement No. 645372.