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Deliverable D6.9
Network Services Evolution and Development

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Abstract

The implementation of Orchestration, Automation and Virtualisation (OAV) helps NRENs build agile network management systems to meet the growing user demands for flexible service delivery. To support the NRENs in this endeavour, the Network Services Evolution and Development task (Task 2) of the Network Technologies and Services Development Work Package (WP6) of the GÉANT project is focused on developing interoperable OAV solutions and enabling knowledge exchange. The Service Provider Architecture Platform (SPA) is a leading example of the usage and advantages of OAV, and the Network Automation eAcademy has been created to improve NREN's OAV knowledge and skills.

Table of Contents

Table of Figures

Table of Tables

Executive Summary

Orchestration, Automation and Virtualisation (OAV) are the key technological drivers for agile network service management platforms - providing flexible, next-generation digital services. The GÉANT community is increasingly aware of the necessity to transform their traditional architectures into automated and interoperable systems that are based on common concepts and principles.

The *Network Services Evolution and Development* task (Task 2) of the *Network Technologies and Services Development* Work Package (WP6) of the GÉANT project is assisting the community through a number of OAV-supporting activities:

- Development of the Network Automation eAcademy, including training materials, terminology documents, architecture analyses and mapping to reference architecture, maturity model assessments, and promotion of the usage of OAV through wiki pages, infographics, and videos.
- Examples of OAV use cases that promote the use of OAV tools and show how to build services using OAV concepts.
- Development of the Service Provider Architecture (SPA) platform based on the TM Forum ODA concepts and principles, using open-source components and open APIs to implement a modular solution that supports the agile management of digital network services.

All of these OAV resources support NRENs on their OAV journey - whether they are just embarking on it or have already taken some steps along the path.

1 Introduction

Research and Education (R&E) organisations are known for their excellence in running high-capacity networks and using state-of-the-art technologies and protocols. The initial needs of their connected institutions regarding capacity and technology remain, while the expectations of the users in the way network services are delivered have evolved with daily use of data and cloud services, IoT devices, artificial intelligence, and self-service provisioning. Users now expect responsive access to agile services. Orchestration, Automation and Virtualisation (OAV) are vital to succeed in this evolution as traditional (manual) processes can neither deliver flexible network services on demand nor drive multi-domain provisioning or the implementation of Self-Organising Networks (SON).

The *Network Services Evolution and Development* task (Task 2) of the *Network Technologies and Services Development* Work Package (WP6) of the GÉANT GN4-3 project is fostering the usage of OAV to help the NRENs in their journey to digital transformation following their inputs summarised in Deliverable D6.2 *Automation and Orchestration of Services in the GÉANT Community* [D6.2].

This deliverable details this work in the following sections:

- Section 2 describes the Network Automation eAcademy which provides the resources that support the NRENs on their OAV journey.
- Section 3 details the development of the Service Provider Architecture based on the basic blueprint for OAV implementation.
- Section 4 summarises the work accomplished by Task 2 and offers conclusions.

Note that preceding work to the Network Automation eAcademy and the Service Provider Architecture can be found in Deliverable D6.6 *Transforming Services with Orchestration and Automation* [D6.6].

2 Network Automation eAcademy

The Network Automation eAcademy provides the work and resources that support the NRENs on their OAV journey. This includes terminology, architecture and mapping documents, training materials, the development of a maturity model, wiki pages, and infographics, as well as videos about orchestration, automation, and virtualisation. All the resources and work have been developed through focus groups, whose work is detailed in the subsections below.

The applicability and usefulness of these approaches were explored in a number of use cases through focus groups. Examples of such use cases, detailed in Section 2.6, are Campus Network Management as a Service (CNaaS), Data Transfer Nodes (DTN) and Intelligent Monitoring (IMONI).

2.1 Terminology

To make it easier to understand existing architectures and solutions, a list of relevant OAV terms and acronyms with standards-based definitions has been compiled and published, aiming to foster commonalities and knowledge exchange among the NRENs.

The resulting document was discussed with the Network Automation Working Group (WG) of the Global Network Advancement Group (GNA-G), and a new version (endorsed and adopted by the GNA-G Network Automation WG as their own reference) was published: Orchestration, Automation and Virtualisation Terminology Version 1.1 [OAV_Term1.1].

The ongoing work within the team identified the need to update the terminology document with new terms in the area of Artificial Intelligence (AI) and Maturity Models, and the work on a third version of the document is currently ongoing.

2.2 Architecture

Following the OAV Architecture considerations and requirements described in Deliverable D6.6 *Transforming Services with Orchestration and Automation* [D6.6], research on the common characteristics of different standards and advanced network architectures was performed. The TM Forum Open Digital Architecture [ODA] was selected as the high-level reference architecture blueprint or Technical Reference Model (TRM). This blueprint is flexible enough to be used by the NRENs as a reference for the creation of digital platforms, new services, and workflows, and to foster interoperability and multi-domain collaboration while maintaining the independence of NRENs to use different technical architectures, processes, and tools inside their domains.

The research initially focused on the concepts, principles, and functionalities to consider when offering digital services in the R&E environment. Some of the requirements considered when selecting the blueprint were service abstraction (with both building blocks and separate components), the usage of open application programming interfaces (APIs), the separation of user/customer engagement from the core network service management, and the implementation of a virtualisation layer to define service objects independent from the underlying infrastructure. The complete study was published in the whitepaper OAV Architectures [WP-OAVARCH].

Figure 2.1. summarises the TM Forum Open Digital Architecture functional blocks.

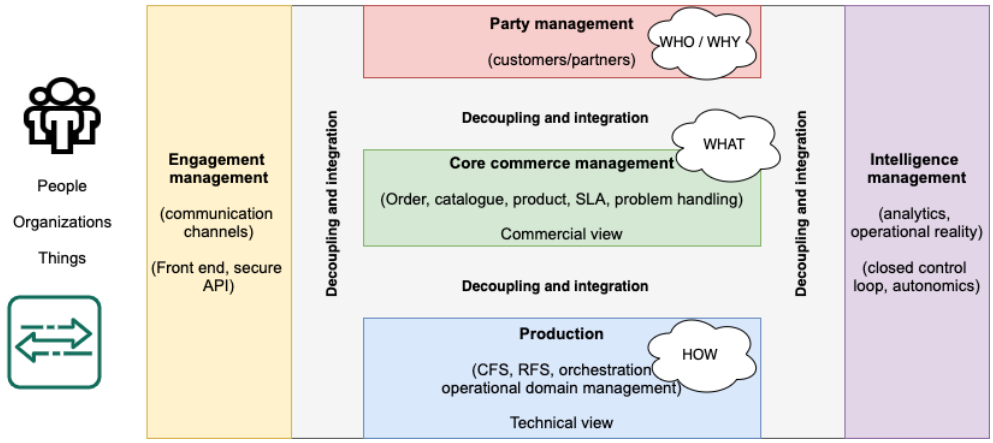

Figure 2.1: ODA Functional block grouping based on [ODAFA]

For more details, please refer to Deliverable D6.6 *Transforming Services with Orchestration and Automation* and the OAV Architectures whitepaper [D6.6] ; [WP-OAVARCH].

Once the OAV architecture blueprint was selected, assistance was offered to users interested in mapping their own OSS/BSS architectures and systems to the blueprint, to support them in analysing their current OAV efforts and provide a common ground for the comparison of different tools and approaches. The mappings published so far are:

- SURFnet OAV Architecture Analysis [MAP-SURF]
- CYNET OAV Architecture Analysis [MAP-CYNET]
- CARNET OAV Architecture Analysis [MAP-CARNET]
- HEANET OAV Architecture Analysis [MAP-HEANET]
- GRNET OAV Architecture Analysis [MAP-GRNET]
- PIONIER OAV Architecture Analysis [MAP-PIONIER]
- NMaaS Architecture Analysis [MAP-NMaaS]

Figure 2.2 presents a mapping of the NMaaS architecture with the selected TM Forum ODA architecture blueprint. The OAV architecture blueprint was used as a reference for the structure of the Network Automation eAcademy.

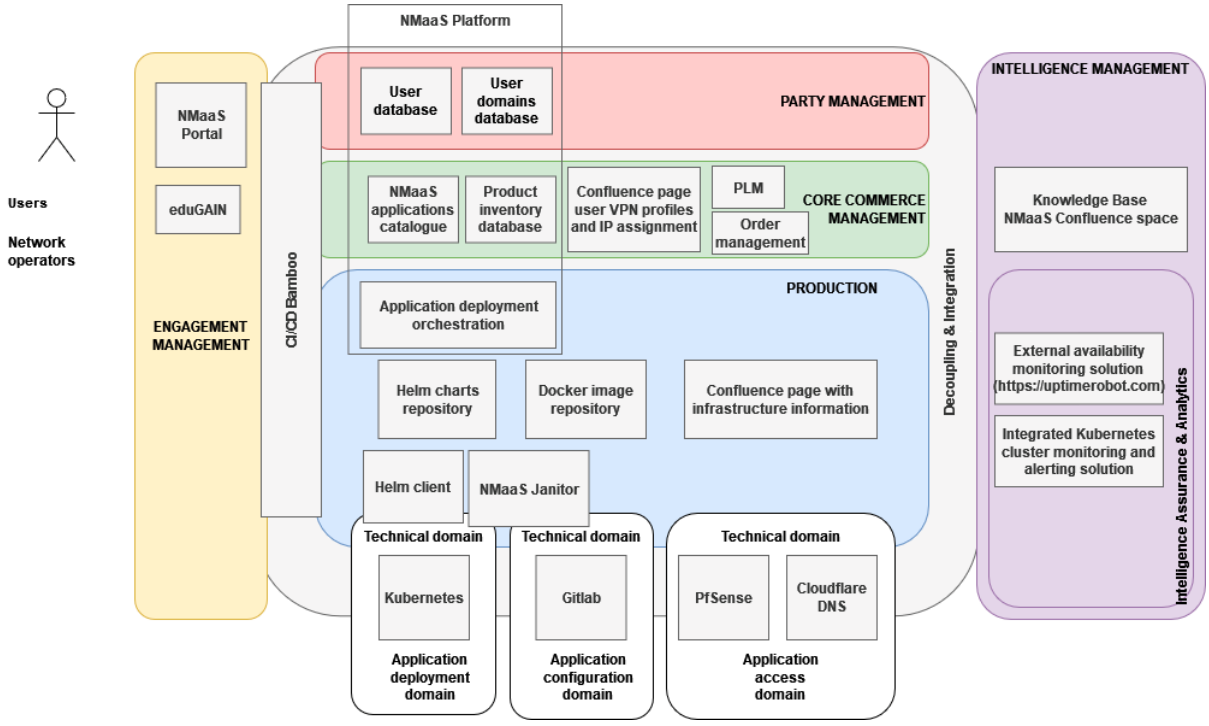

Figure 2.2: NMaaS - ODA architecture mapping

2.3 Training Program

Network engineers, managers, and members of the R&E networking community need to add new theoretical and practical OAV concepts and knowledge to their existing skill sets to be able to provision services through digital platforms. However, operating a network is demanding with the all-too-frequently scarce resources that are typically available. Following the feedback summarised in Deliverable D6.2 *Automation and Orchestration of Services in the GÉANT Community* [D6.2] a training programme was created [NAEACADEMY] and integrated with the GÉANT eAcademy platform.

This self-paced programme, 'by the community, for the community', introduces the principles of the functional blocks of the TM Forum Open Digital Architecture (ODA), DevOps concepts, protocols, tools, real-life examples, and resources from the R&E world to provide context and inspire innovation through short learning units and use case studies. These are presented as an interactive metro map under the OAV Training Portal [NAEA-WIKI] and the GÉANT Learning and Development eAcademy [NAEA-GLAD]. Each "station" represents a learning unit (see Figure 2.3), and, as with real metro maps, learners can follow a variety of paths (introductory, technical, or theoretical), change from one line to another or skip stations - as each unit indicates both its prerequisites and recommended units to follow it.

The learning units are also presented as packages classified according to the OAV blueprint functional blocks and related concepts:

- Open Digital Architecture
- CI/CD
- Modelling
- Formats & Protocols
- APIs
- Engagement Management
- Party Management
- Core Commerce Management
- Production
- Intelligence Management
- Architecture Deep Dive
- Use Cases & Examples
- OAV Architectures
- Virtualisation
- Automation and Orchestration

Note that the metro map shown in Figure 2.3 is constantly updated to ensure it remains current. The latest version can be viewed online [Metro].

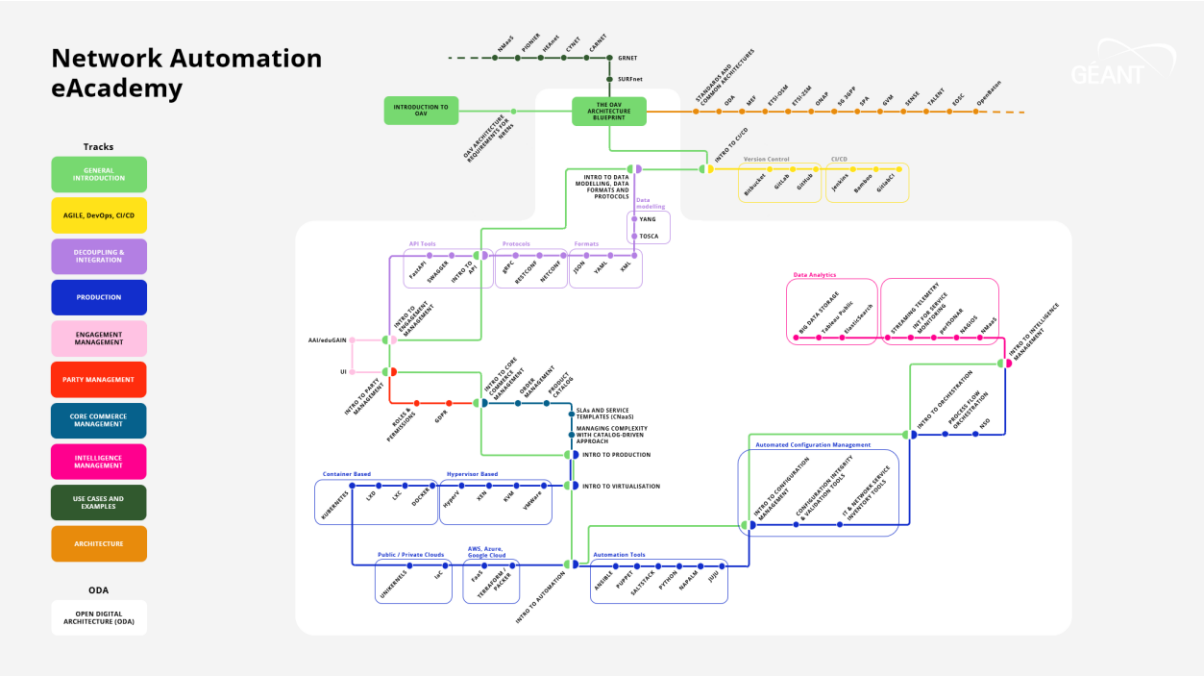

Figure 2.3: Training Metro Map

The learning units hosted by the GÉANT eAcademy (a Moodle platform managed and supported by the GLAD team) include subtitled videos and corresponding PDFs with the slides and the video scripts so users can follow either the videos or download the PDFs to read separately. R&E network services examples are also included. More technical units also contain hands-on exercises. Useful links are included in each unit to build on the information in the videos, slides, and hands-on exercises. Each unit is typically followed by a quiz (to test the user's knowledge) as well as a feedback form to allow the training team to gather input for further development and improvement. Users receive a certificate of completion when a learning unit is completed. External links, white papers, presentations, and other documents are included as recommended additional reading.

The 21 units published so far (summarised in Table 2.1) include three general introduction units, five units to introduce the TM Forum functional blocks, two on DevOps concepts, seven on the Decoupling and Integration part of the OAV architecture, and five on the Production part.

Area	Learning units
General Introduction to OAV	OAV - Introduction [NAEA-OAV-IN]
	OAV Architecture Requirements for NRENs [NAEA-OAV-NREN]
	The OAV Architecture Blueprint [NAEA-OAV-ARCH]
Introduction to TM Forum ODA Functional blocks	Introduction to Engagement Management [NAEA-OAV-ENG]
	Introduction to Party Management [NAEA-OAV-PARTY]
	Introduction to Core Commerce Management [NAEA-OAV-CORE]
	Introduction to Production [NAEA-OAV-PRO]
	Introduction to Intelligence Management [NAEA-OAV-INT]
DevOps	Introduction to CI/CD [NAEA-CICD]
	CI/CD: GitlabCI [NAEA-GITLABCI]
Decoupling and Integration	Introduction to Data Modelling, Data Formats, and Protocols [NAEA-I-DATA]
	Data Modelling: YANG [NAEA-YANG]
	Formats: XML [NAEA-XML]
	Formats: YAML [NAEA-YAML]
	Formats: JSON [NAEA-JSON]
	Protocols: NETCONF [NAEA-NETCONF]
	Introduction to API [NAEA-API]
Production	Introduction to Virtualisation [NAEA-I-VIR]
	Introduction to Automation [NAEA-AUT]
	Automation Tools: Ansible [NAEA-ANSIBLE]
	Introduction to Configuration Management [NAEA-CONFIG]
	Orchestration: NSO [NAEA-NSO]

Table 2.1: Learning units published under the Network Automation eAcademy

The Network Automation eAcademy team offers learners its support and free consultancy services. Trainees can join the trainers in a video conferencing call, ask questions related to training, architecture blueprint and mapping, and/or suggest the creation of new units. So far, the units have been followed by a minimum of 400 different users (corresponding to the most visited unit), with

more than 1,300 users in total for all of them, and more than 30.000 total visits to the different sections.

2.4 Maturity Model

As shown in D6.2 [D6.2] (and based on the architecture mappings) there are different levels of OAV adoption among the NRENs, with different approaches taken. As a result, a focus group was defined in the Task to design and provide a tool for organisations to assess the current level of maturity of their OAV-related systems and processes. The work on Maturity model design and definition has started (and is still ongoing) with the definition of dimensions in scope, maturity stages and levels, progressing towards the definition of assessment questions that will need to be answered. The maturity model assessment tool will then be offered to organisations for self-evaluation.

2.5 Dissemination Activities

All activities conducted as a part of the Network Automation eAcademy have been promoted and their results disseminated in several events and community meetings such as:

- The TNC21 BoF *Orchestration, Automation and Virtualisation: Focusing on the user* [OAV-BoF] (recording available in [OAV-BoF-video]).
- The Infoshare 'Orchestration, Automation and Virtualisation: Ready, Steady, Go!' [OAV_info].
- The 15th SIG-NOC meeting [15-SIG-NOC], the ESNOG meeting [ESNOG27].
- The 16th SIG-NOC meeting [16-SIG-NOC].

Specific Infoshares about some use cases have also been organised and are detailed in Section 2.6.

A presentation on the Network Automation eAcademy was accepted for TNC22 as a lightning talk [TNC22].

In addition, a short video has been created in a collaboration with WP2 to raise awareness about the benefits of the adoption of automation and the resources WP6 T2 created for the NRENs. It is available on the GÉANT YouTube channel [OAV-VIDEO] and linked to from both the NETDEV Wiki and the GLAD eAcademy.

A visual overview of how to introduce service abstraction to the NRENs, as well as some digital platform concepts and principles was published in the pamphlet *Towards Collective Digital Services* and an infographic on the OAV journey [OAV-PAM].

The Network Technologies and Services Development wiki [NETDEV-WIKI] is a platform for knowledge sharing between GÉANT, NRENs, and organisations. It includes information on production services and software, research and development, digital architecture and automation, and applied automation use cases. The wiki pages include the Community Portal [OAV-COMM-PORTAL] (with examples of automation), and the OAV Training portal with the Network Automation eAcademy, mappings, presentations, etc.

2.6 Use Cases

This section presents use cases of OAV principles being applied in R&E networking. Some WP6 T2 focus groups have worked on such applied orchestration, automation and virtualisation use cases. The first case, CNaaS, is an example of a service that could not be offered at any scale without OAV. The second case, DTN deployment, is a use case where a service can be easily deployed and reach more institutions and researchers thanks to the usage of OAV. The third case, IMONI, is the on-going work to study the feasibility of the deployment of an automated monitoring platform, as a step towards the management of intelligent networks with intelligent monitoring.

2.6.1 CNaaS

Campus Network Management As A Service (CNaaS) is a use case of network automation and orchestration in production services offered by some NRENs, as they would be nearly impossible to offer at any scale without using OAV for the network setup and configuration. The OAV Community Portal and the CNaaS sections on the wiki [OAV-CNaaS] include several examples from NRENs offering CNaaS services using OAV.

Three Infoshares on CNaaS have been organised since the beginning of the project. The most recent one was *Network Management as A Service* [INFO-CNaaS-3] in May 2022, with the collaboration of NRENs and universities that presented their use cases, lessons learnt, and their preferred tools for Campus Management. The recording of the event is available on the GÉANT YouTube channel [CNaaS-3-VIDEO].

A mailing list (cnaas-discuss@lists.geant.org) and a dedicated Slack channel were created to foster further discussions.

2.6.2 DTN

The deployment of DTNs can benefit from the use of automation and virtualisation. The DTN focus group in WP6 T2 was created to provide guidance to NRENs looking to support scientists that need to transfer large amounts of data. Initiated with a survey, many NRENs indicated throughput issues as almost always being in the “last mile”, i.e., within the campus or local networks of the organisations running the data transfers. A readily deployable and virtualised / containerised DTN service could be of benefit to such users, combined with Science DMZ principles [DMZ].

For this reason, the DTN wiki [DTN_wiki] was created to include guidelines and documentation, as well as several examples of virtualisation of DTNs. The *Data Transfer Node (DTN) Tests on the GÉANT Testbeds Service (GTS)* whitepaper [DTN_WP] and the Infoshare *Data Transfer Nodes: How Fast Can Your Data Travel?* [DTN_info] show how to automate the creation of DTNs.

A mailing list (dtn-discuss@lists.geant.org) and a dedicated Slack channel were created to facilitate further discussion.

2.6.3 IMONI

The Intelligent MONItoring (IMONI) focus group was established to explore the need and potential for additional analysis and correlation of data gathered from multiple different monitoring systems, in one or in multiple organisations. In the requirements gathering phase, the team is looking at potential data sources, use cases, and data models with the aim of investigating the possibility of creating an OAV platform that could combine and integrate time-series data from multiple data sources on a single universal GUI, and offer the ability to build custom dashboards tailored to the individual needs of organisations.

3 Network Service Transformation with SPA Platform Components

The Service Provider Architecture (SPA) represents a blueprint for the implementation of a microservices-based modular digital service management platform that embodies the TM Forum ODA guidelines and principles. The principal idea behind SPA is to move away from siloed monolithic solutions used for single service management to modular, flexible designs based on orchestration of independent functional components that are consistently used for all service management actions.

The SPA development team is focused on the efforts of showcasing how to achieve this network service transformation with the implementation and continuous development of the SPA platform. The blueprint of the SPA design is presented in Figure 3.1 (mapped with the ODA architecture) and its main functional components are discussed in more detail in Deliverable D6.6 *Transforming Services with Orchestration and Automation* [D6.6].

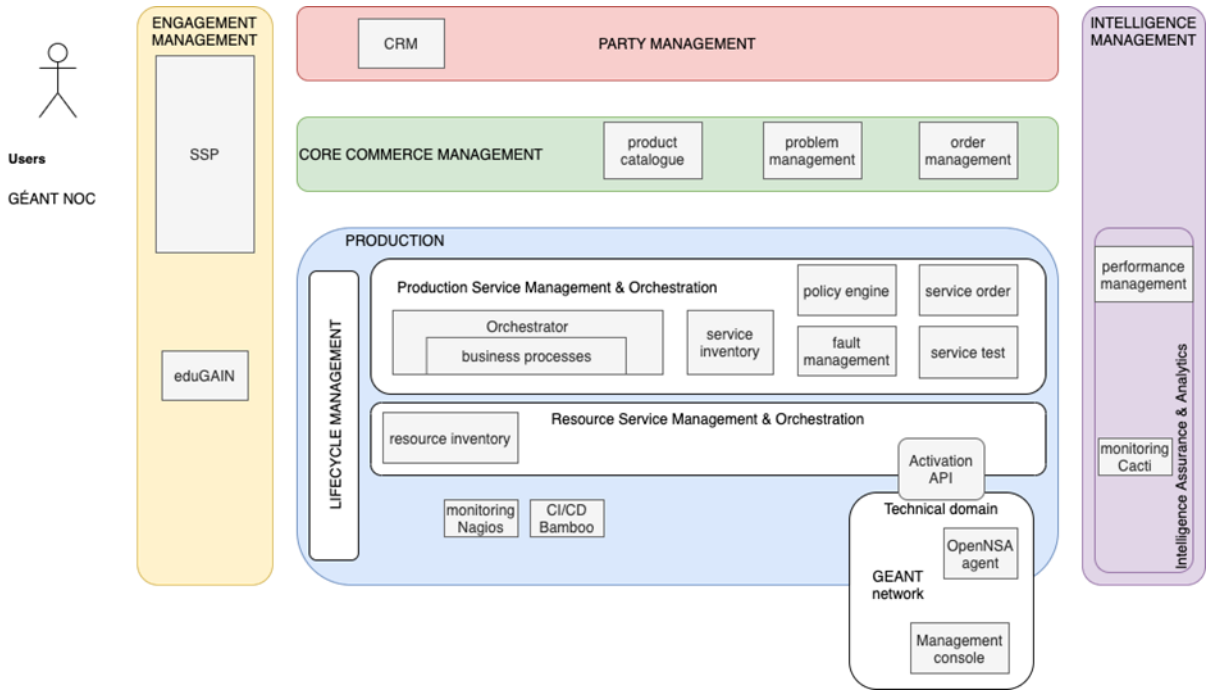

Figure 3.1: SPA components mapped to the ODA functional blocks

The SPA platform design and development is carried out in collaboration with the GN4-3 WP7 team that is in charge of the GÉANT network core infrastructure, and core service evolution and operations. Infrastructure changes to the deployment process, additional components and upgrades, as well as

improvements to the development and testing environment have been implemented to address the gathered requirements. In addition to serving as the service management platform for the GÉANT Connection Service (GCS), the SPA platform components are being further enhanced to support the requirements of the Multi-Domain – Virtual Private Network (MD-VPN) and GÉANT IP services.

The SPA Inventory is being investigated for adoption by other NRENs. To facilitate testing SPA as a platform or SPA Inventory as a standalone component, both are now being offered through the NMaaS service [NMS]. This provides users with an easily accessible sandbox environment where users can familiarise themselves with and test the main SPA functionalities.

The idea of building a digital platform such as SPA and the possibility to reuse its components within the community has also been promoted in the GÉANT Connect Magazine [GCM] and on TNC22 [TPT].

SPA is used in production for the GÉANT Connection Service and work is ongoing to use it also for MD-VPN and GÉANT IP services, as presented in Sections 3.1, 3.2, and 3.3. Its Service Inventory is being considered for use in the PIONIER network in Poland (see Section 3.4). Additional work is ongoing to provide the SPA platform using containers (see Section 3.5), to make some of the SPA components available on the NMaaS platform (see Section 3.6), and to add new supporting tools for SPA (see Section 3.7).

3.1 GÉANT Connection Service

There have been several upgrades to the SPA platform that have resulted in a more flexible, high-performing SPA deployment. These upgrades have been pushed to the production environment in a new major version release (SPA v1.3), coinciding with a major upgrade of OpenNSA to version 3.1.

The newly deployed production version of SPA is now used to set up GCS circuits across the whole GÉANT network, where all GÉANT routers now supporting OpenNSA 3.1 are used to support the establishment of Microsoft Express Route circuits. This expansion of the network topology footprint has substantially increased the data managed in the SPA resource inventory. The inventory now counts 40 routers which is a 3 times increase in topology information management compared to the period before the topology extension. Accordingly, the number of managed active circuits has increased 10 times, currently reaching around 50 active circuits at any given moment. The automated processes related to circuit management such as provisioning, changing, or terminating a circuit implemented using SPA enable GÉANT Operations network engineers to set up circuits in about 2 minutes, a significant saving of time and human effort compared to the previously manual configuration, while also delivering a customised dashboard with all necessary information provided by the SPA Self-Service Portal.

To ensure smooth operation and a responsive graphical interface for the end-users, several SPA components have been tested and their performance improved. This includes the Self-Service Portal (SSP), API wrappers and the inventory. Due to the improvements to the inventory API advanced paging and filtering are now supported, preventing the SSP from unnecessary caching and further selection of data to display. The joint component upgrades have significantly boosted the performances of the SPA platform. The new versions of the SPA components can now manage a very large number of service instances and a vast resource inventory topology.

Part of the major SPA version release in the production is the addition of a graphical user interface for full network topology management as presented in Figure 3.2.

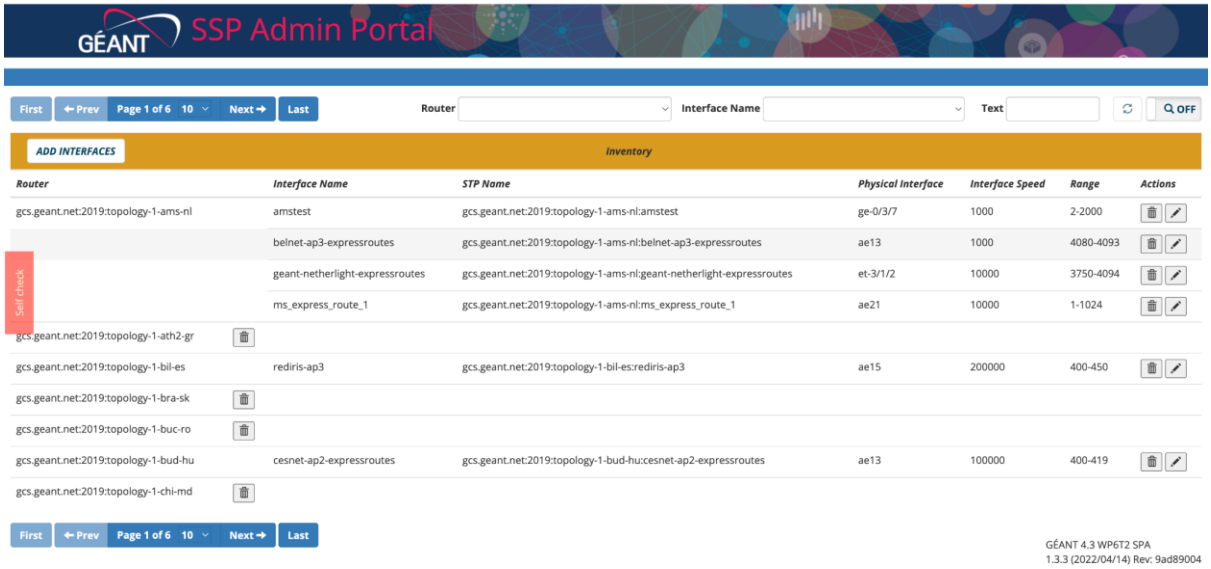

Figure 3.2: SPA production resource inventory - OpenNSA network topology management for GCS

The inventory pages of the SPA SSP enable the end-users (GÉANT OC team) to edit the network topology that is used by OpenNSA to manage circuits across the GÉANT network. The users can view the complete topology, use advanced search to find a particular item, and edit or delete routers, interfaces and service termination points (STPs). The logic implemented in SPA provides validation checks when using the inventory so that a user cannot delete STPs in use, define overlapping VLAN ranges, etc. Once a change is saved in the network topology, SPA pushes this information to the OpenNSA topology manager which reacts according to the newly received information. With these changes, the SPA Inventory has become the single point of truth resource inventory for GCS. The OpenNSA topology manager always refers to the SPA Inventory to get the correct inventory information.

Another major change that the SPA development team has been working on is the migration from Activiti to Camunda as the main orchestration engine for SPA. The change of the underlying orchestration engine that is in charge of controlling all automated processes that are activated and run in SPA was done after a careful investigation of the current status and future development plans of the old Activiti orchestration solution and other existing open-source orchestration engines. Due to the work on Activiti slowing down during the past few years and the tool's community becoming more focused on the development of commercial solutions, the SPA team decided that a migration to Camunda [CAM] would enable access to an active open-source community that provides more frequent upgrades and up-to-date support. Camunda has been chosen as it is a new “fork” initiative based on the original Activiti, thus requiring minimum migration changes to further support an event-driven microservices architecture. After the initial testing phase, all SPA instances in the development, testing, and production environments are now implemented using the Camunda orchestration engine.

To be able to easily debug identified issues or track specific service instances, an upgrade of the service testing component has been implemented. This can be invoked on demand from a command line interface (CLI) in addition to the automated regular testing functionality. The developed CLI for GCS service testing enables developers to significantly reduce the time needed to test applied fixes and new functionalities, enabling the user to activate any SPA process using a single command, or to invoke a series of processes with a simple script. A special user and role are associated with the use of the CLI service testing activities so that they can easily be tracked within any SPA component.

For the purposes of the joint major version release, aiming to increase the automation of next version deliveries and enhance the end-users' testing experience, WP6 and WP7 have created a joint User Acceptance Testing (UAT) environment where all new requirements and changes are pushed for testing before they are deployed in the production environment. The UAT setup fully replicates the production environment to ensure that, once a change is accepted, the deployment in production will be a stable replica of the UAT environment. Processes have been put in place to ensure that a full rollback to stable version is possible in case there is a problem with the new version in the production environment.

During the development, testing, and deployment of the new SPA components and infrastructure environments, care has been taken to ensure that all documentation is updated accordingly. This process ensures the continuous maintenance of a knowledge base that has proved very valuable, especially for new members.

The current work on supporting GCS includes the development of rules that will enable fine-grained permissions control of SSP users. This feature is being implemented by integrating Camunda with the Drools business rules management system [DRS], which decides whether the next steps in a given process should be carried out or not, based on the gathered information. Further enhancements regarding the inventory API are also underway, aligned with the rest of the activities of the SPA development team.

3.2 MD-VPN

The SPA resource inventory together with the SPA user database component have been identified as potential supporting components for the development of a single point of truth for the MD-VPN service. The work that initially started by doing a comparative analysis of the SPA data model and the original MD-VPN service inventory data model is now continuing further. The data model for the SPA Customer Relationship Management (CRM) component has been implemented to completely support storing all stakeholder (Party) information relevant to the MD-VPN. This has required further extending the CRM with additional Party characteristics and with extra relationships between the entities that will enable defining the way they interact when implementing MD-VPN.

The newly made changes to the SPA Inventory in terms of API improvements and enhancements, especially regarding filtering, have also been aligned with the MD-VPN requirements, so that the new version of the SPA Inventory can fully support the MD-VPN resource and service descriptions, and ensure its fast and flexible retrieval. This work continues with exploring more flexible options for storing and retrieving MD-VPN-related data.

3.3 GÉANT IP

In collaboration with WP7, the SPA team is working on the automation of the GÉANT IP service. During the initial phase, the main task is to enable the implementation of the golden configuration [GCO] that represents a repository of configuration snippets that should be used for consistent, standardised device configuration. To implement the golden configuration approach, a single source of truth is needed and will be provided by the SPA service and resource inventory.

The work started with the definition of a data model that will be used to describe the resources used by the GÉANT IP service as well as all of the service elements and characteristics. The data model is aligned with the data models that describe GÉANT GCS and MD-VPN, allowing a single instance of SPA to store the information about all types of service and resource instances.

The next step is to enable topology management of the GÉANT IP resource information that is stored in the inventory. For these purposes a pilot inventory management interface is being developed in the SSP, see Figure 3.3.

GÉANT IP

Routers

Hostname	Brand	Model	Location	IPv4 loopback	IPv6 loopback
1-0-0-iface	None	None	None	None	None
6-1-iface	None	None	None	None	None
7-1-iface	None	None	None	None	None
core1.spa.private	Juniper	vmx	eve_site1	10.10.10.10	2001:dead:beef::1
core2.spa.private	Juniper	vmx	Unknown	10.10.10.20/32	2001:dead:beef::2/128
core3.spa.private	Juniper	vmx	Unknown	10.10.10.30/32	2001:dead:beef::3/128
dfn.dexite	None	None	None	None	None
geant.org	None	None	None	162.13.218.132	2a00:1a48:15e1:0:688:f90a:2924:500
if0/0	None	None	None	None	None
jorge1.test	None	None	None	None	None
mx2.lab.office.geant.net	Juniper	MX960	Cambridge, UK ##LOC 52.205276 N 0.119167E##	62.40.96.28	2001:798:aa:1::7
mx5.lab.office.geant.net		MX480	Cambridge, UK ##LOC 52.205276 N 0.119167E##	62.40.96.40	2001:798:aa:1::b
rt1.lab.office.geant.net	Juniper	MX204	Cambridge, UK ##LOC 52.205276 N 0.119167E##	62.40.96.27	2001:798:aa:1::6
rt3.lab.office.geant.net	Juniper	MX204	Cambridge, UK ##LOC 52.205276 N 0.119167E##	62.40.96.29	2001:798:aa:1::8
rt4.lab.office.geant.net	Juniper	MX204	Cambridge, UK ##LOC 52.205276 N 0.119167E##	62.40.96.30	2001:798:aa:1::9
win-labor.dfn.de	None	None	None	131.188.16.206	2001:638:a000:1080::206

Physical Interfaces

Public Identifier	MAC	Name	Description	Template
1-0-0-iface	None	None	None	None
1-0-0-iface@win-labor.dfn.de	None	None	None	None

Figure 3.3: Pilot inventory GUI for GÉANT IP topology management

In the GÉANT IP topology management scenario, when a GÉANT NOC user makes changes in the GÉANT IP resource topology using the SPA SSP, these changes will be pushed to a specially developed wrapper and validator, see Figure 3.4. This wrapper client will then interface with Ansible, which is used for automated network configuration management [ANS], to validate and further augment the information that will finally be stored and kept in the SPA Inventory. For these purposes, the specially developed wrapper exposes the same inventory API to the SSP, making the addition of another service-specific validation layer on top of the SPA Inventory transparent to the outside world (in this case, the SPA SSP).

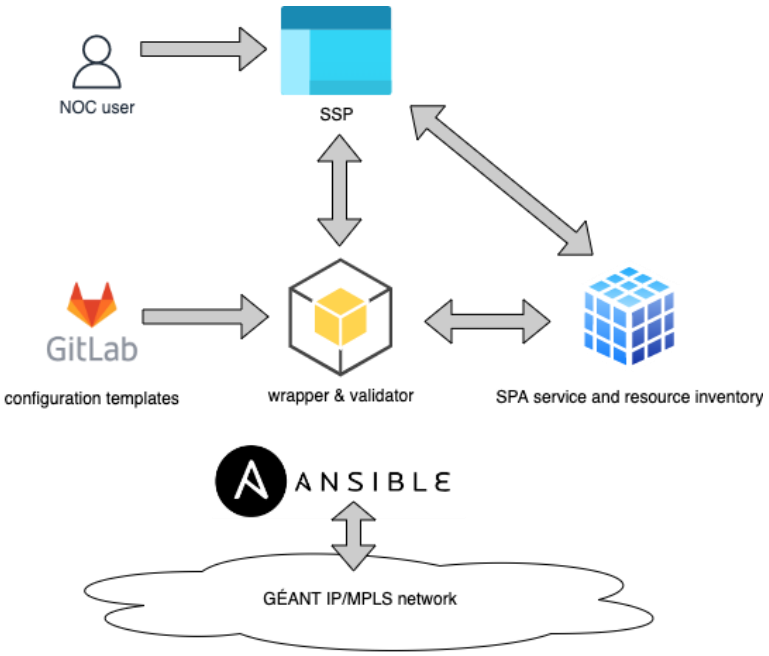

Figure 3.4: Implementing the golden configuration for GÉANT IP

The golden configuration implementation is envisioned to be based on the configuration templates stored on GitLab combined with the information stored in the SPA Inventory. Via the wrapper, Ansible will be able to access and use this information to create and push the necessary configuration changes to the GÉANT network. Currently, the SPA team is focusing on completing the topology management by taking advantage of the inventory API upgrades that have been implemented while working on GÉANT GCS. Once this phase is completed, work will continue towards the design and specification of the service management orchestration processes.

3.4 Service and Resource Inventory in PIONIER

Like GÉANT, PSNC, the operator of the national PIONIER R&E network in Poland [PIO], sees the need to introduce automation mechanisms to manage network infrastructure and services. The increasing number of different types of resources and the level of complexity associated with the configuration and integration of different systems requires a comprehensive approach based on standards and open interfaces.

PSNC is in the process of building a coherent platform consisting of multiple components that can communicate and share data. As part of this work, the SPA system components are taken into consideration for becoming a part of the platform. The first and primary component is the SPA Inventory, which will be used as a single source of truth to automate the configuration of network resources and services. Work on the data model has already started with the help from the SPA development team. This effort is also being coordinated with the GÉANT automation team so that future implementations used in both networks will be compatible. This way, the experience gathered by the SPA development team while working on the GCS service (extending interfaces, rapid introduction of new functionalities, troubleshooting, testing, etc.) can be used to help extend and adapt the inventory for PSNC. Once the production deployment of the SPA Inventory in PIONIER is

completed, other SPA components, including the self-service portal, CRM, and the orchestrator will be analysed for integration into the PIONIER platform.

3.5 Using Containers for the SPA Platform

To speed up and simplify the installation of SPA components, they are now being prepared for Docker containers. The transition to Docker containers will also ensure the use of the correct versions of programming libraries and software necessary for the proper operation of the components.

Currently, container images are used in the GCS UAT (pre-production) test environment. The images are also planned to be deployed in the GCS production environment using full or partial automation of the CI/CD process.

It has been observed that the ability to install SPA using containers helps PSNC and the GÉANT teams that are testing the SPA components.

3.6 SPA in NMaaS

To promote the SPA platform and to facilitate testing the E-Line service (point-to-point L2 connections) [MEF] using the OpenNSA application, it was decided to allow users to run test instances of the SPA platform on the NMaaS system [NMS]. This system (Platform as a Service (PaaS)) provides a virtual space for the applications (see Figure 3.5), without having to own hardware resources and having the technical knowledge these require. One of the main requirements for adopting SPA in NMaaS was simplicity of use and configuration with default settings. This allows users to focus on familiarising themselves with SPA operation instead of having to install and configure all SPA components.

At the moment, E-Line with the SPA components served from NMaaS is intended for tests, however, in the future it will be possible to prepare a version for production use (see Figure 3.6). Network operators and projects will be able to integrate SPA instances to manage the E-Line services (or other) in their network infrastructures.

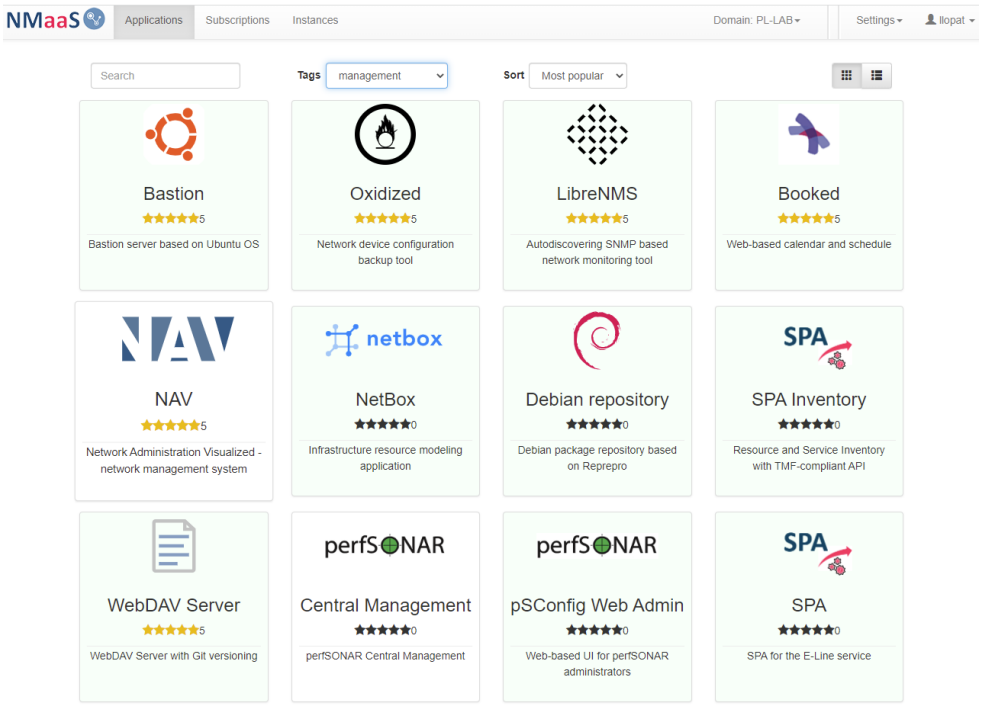

Figure 3.5: A part of the application catalogue in NMaaS

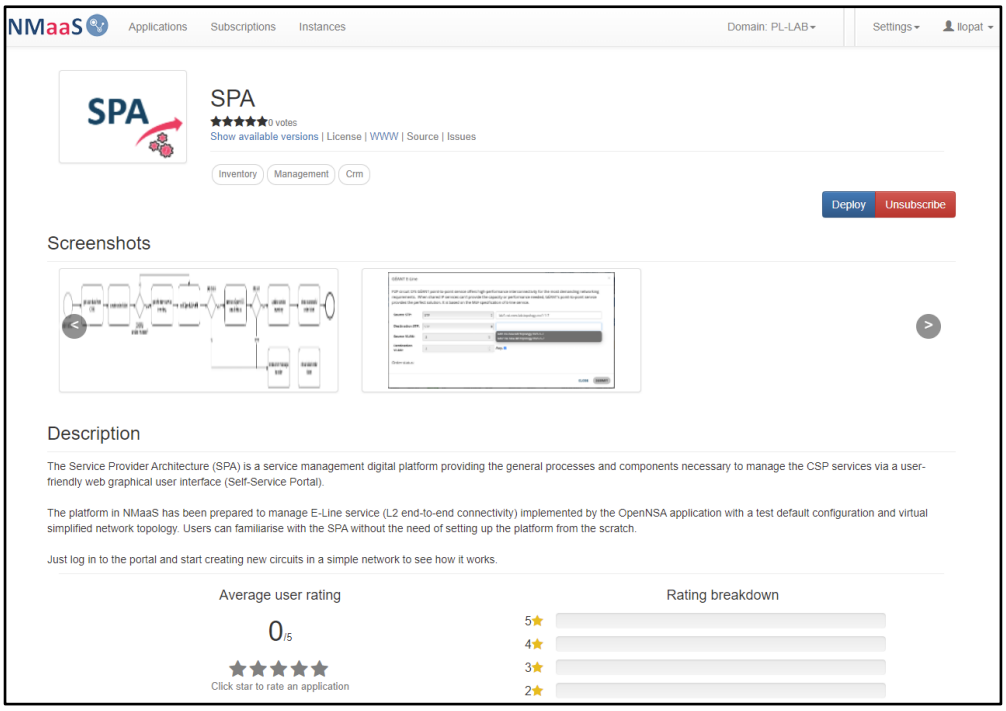

Figure 3.6: The SPA application used to run the E-Line service in NMaaS

3.7 New SPA supporting tools

To test the GCS service but also to create backups, a simple application, called NRM-Parser, was created to retrieve data from the SPA Inventory via a REST interface and then store it as native OpenNSA topology files (the original format for storing the abstract network topology managed by the OpenNSA application).

The Inventory Service Uploader application, developed in recent months, is used to recreate service data in the SPA Inventory from a previously created backup file in JSON format. This file is created by retrieving the complete service information (circuits) from the SPA Inventory using a REST interface. This application is also used for testing and backups of the GCS service.

4 Conclusions

The *Network Services Evolution and Development* task (Task 2) of GN4-3 WP6 is engaged in multiple activities that aim to help the community advance in the areas of orchestration, automation and virtualisation (OAV). The OAV resources that have been created by the focus groups and made available via the Network Automation eAcademy and NETDEV wiki offer the community a common approach and a set of open principles that provide solid footing for their OAV efforts. By promoting a high-level architectural blueprint, the Task can help guide the community efforts towards building interoperable systems that can then be integrated in an ecosystem platform, supporting the development of dynamic multi-domain services.

Recognising the different levels of maturity in experience and implementation of OAV solutions, the Task has analysed the architecture of the tools and systems used by different NRENs. This helps the NRENs assess their current status and identify common approaches in the community that enable knowledge and experience exchange when it comes to testing and integrating new tools in the production networks. The analysis has also led to the development of the suite of training material provided through the Network Automation eAcademy, which helps to address the need for further OAV skills development by providing targeted self-paced courses to the GÉANT community. The development of these OAV resources through the Network Automation eAcademy will continue throughout the project to provide help and support to all parties on a digital transformation journey. Moreover, the Project Lifecycle Management process (PLM gate) has started to transform the Network Automation eAcademy into a production service.

In addition to the supporting OAV resources, WP6 T2 is also focusing on practical implementations of the promoted open concepts and principles that should lead to the creation of automated agile service management platforms. The CNaaS, DTN, and IMONI use cases show examples of implementations of next generation user-centric network services, while SPA represents a flagship implementation of a full digital platform using open-source tools that can be flexibly combined. While the SPA platform is currently used to manage the lifecycle of the GCS production service, its components are also being extended to support additional services such as MD-VPN and the GÉANT IP service, showing the power of reusing the same components to manage multiple services, compared to the traditional siloed approach that can be found in many traditional network management systems.

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Glossary

API	Application Programming Interface
BOF	Birds Of a Feather
BSS	Business Support System
CD	Continuous Development
CI	Continuous Integration
CLI	Command Line Interface
CNaaS	Campus Network management as a Service
CRM	Customer Relationship Management
DMZ	Demilitarized Zone
DTN	Data Transfer Nodes
ESNOG	Grupo de Operadores de Red Españoles
GCS	GÉANT Connection Service
GLAD	GÉANT Learning and Development
GNA-G	Global Network Advancement Group
GUI	Graphical User Interface
IMONI	Intelligent Monitoring
IoT	Internet of Things
JSON	JavaScript Object Notation
MD-VPN	Multi Domain Virtual Private Network
NETCONF	Network Configuration
NETDEV	Network Technologies and Services Development
NMaaS	Network Management as a Service
NOC	Network Operations Centre
NREN	National Research and Education Network
NSO	Network Service Orchestration
OAV	Orchestration, Automation and Virtualisation
OC	Operations Centre
ODA	Open Digital Architecture
OSS	Operations Support System
PDF	Portable Document Format
R&E	Research and Education
SIG	Special Interest Group
SON	Self-Organising Networks
SPA	Service Provider Architecture
SSP	Self-Service Portal
STP	Service Termination Point
TRM	Technical Reference Model
UAT	User Acceptance Testing

VLAN	Virtual Local Area Network
WG	Working Group
WP	Work Package
XML	eXtensible Markup Language
YANG	Yet Another Next Generation