

02-05-2018

Deliverable D8.7 Network Management as a Service Production Service

Deliverable D8.7

Contractual Date:	30-04-2018
Actual Date:	02-05-2018
Grant Agreement No.:	731122
Work Package/Activity:	8/JRA2
Task Item:	Task 5
Nature of Deliverable:	Report
Dissemination Level:	PU (Public)
Lead Partner:	PSNC
Document ID:	GN4-2-18-32D593
Authors:	L. Lopatowski (PSNC), F. Loui (Renater), I. Golub (PSNC), J. Gutkowski (PSNC), R. Lui (GÉANT), A. Radhakrishnan (GÉANT)

© GÉANT Association on behalf of the GN4-2 project.

The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 731122 (GN4-2).

Abstract

During Period 2 of the GN4-2 project, Network Management as a Service is being prepared to transition into a production service. NMaaS service elements are presented in this document, including the service benefits, users, technology and architecture, as well as the service operational aspects and the next version roadmap.

Table of Contents

Executive Summary	1
1 Introduction	2
1.1 Network Management as a Service	2
1.2 Service Description	3
1.3 Service Benefits	4
2 Service Users	4
2.1 Small or Emerging NREs	5
2.2 Small Organisations	5
2.3 GÉANT Community	5
3 Technical Description	6
3.1 NMaaS Architecture	6
3.2 NMaaS User Roles and Processes	11
4 Service Operations	13
4.1 Supporting Infrastructure	13
4.2 Operations and Support Teams	13
4.3 Service Policies	14
4.4 Service Metrics	14
5 Service Roadmap	14
6 Conclusions	15
References	16

Table of Figures

Figure 3.1: NMaaS system components	7
Figure 3.2: NMaaS portal tools view	8

Executive Summary

Network Management as a Service (NMaaS) provides a portfolio of network management applications run on a per-user, secured network monitoring infrastructure. GÉANT's NMaaS service includes three aspects: providing, managing and maintaining the infrastructure of the NMaaS service portal, platform and selected tools, supporting users in using the system, and the selected tools for monitoring their networks via NMaaS, as well as supporting users that contribute their software to NMaaS system.

NMaaS users are organisations that do not want to own NMS infrastructure themselves and/or want to outsource network management, as well as organisations and/or individuals that are searching for quality network management software or who want to share their software within the community.

NMaaS provides multiple benefits, as a system, an application marketplace, and as a service. NMaaS simplifies domain network management by providing the infrastructure and tools via a cloud-based, multi-tenant and secure network management system. It enables the deployment of network management tools, as well as management and monitoring of client networks, although NMaaS does not monitor and manage the network by itself. The selection of tools that is and/or can be made available to users is not limited to network management tools and can be easily extended. With NMaaS, users do not have to bear the ownership costs and risks related to maintenance and control of the network management infrastructure.

NMaaS is being developed as a part of the GÉANT Network 4, Phase 2 project (GN4-2) within the Network Services Development (JRA2) project activity. This document provides more information about the NMaaS service, including technical and service description, benefits, operational details and future roadmap.

1 Introduction

Network Management as a Service (NMaaS) is a new development effort in GN4-2. This work is being carried out as a stand-alone NMaaS task (Task 5) of the Network Services Development Joint Research Activity (JRA2), based on the initial proposal from the French NREN, Renater.

NMaaS simplifies domain network management by providing the infrastructure and tools via a cloud-based, multi-tenant and secure network management system. It enables management and monitoring of client networks through on-demand deployment of network management tools in the cloud infrastructure.

The NMaaS service consists of three components. The first component includes providing, managing and maintaining the infrastructure of the NMaaS portal, platform and selected tools. As a second service aspect, NMaaS provides support to users in using the system and the tools they select for monitoring their networks via NMaaS. The third component entails user support, when contributing their software to NMaaS portfolio. Although the initial set of tools is focused on network monitoring, the system itself is created to accept the integration of any tool needed.

This document gives an overview of the NMaaS service that GÉANT will provide to its users.

Section 2 describes the service, beginning with an explanation of NMaaS and including the service's benefits. This also includes a description of NMaaS user groups.

Section 3 provides a technical description and Section 4 considers service operations, covering supporting infrastructure, operations and support team, policies and metrics.

Section 5 explains the NMaaS service roadmap. Conclusions are summarised in Section 6.

1.1 Network Management as a Service

Network Management as a Service provides a portfolio of network management applications that are run on a network monitoring infrastructure established for a particular user that requested the service. The established infrastructure is secured for that particular user and does not interlace with the NMaaS instance established for any other user. NMaaS includes:

- A system for network management, including:
 - NMaaS platform – core service application.
 - Virtualised infrastructure – cloud resources (Kubernetes cluster), secure DCN networks [[Kubernetes](#)].

- Supporting infrastructure - tool image registry, file repository.
- Offered tools
- NMaaS portal – web-based application marketplace.
- A service providing user support and managing the infrastructure.

The NMaaS system supports the process of adding new tools, offers integrated tool selection, on-demand initiation and termination of the service orchestration process, which results in per-user service instantiation, as well as acting as a dedicated network management system for each registered user. Users access the system via the portal, which supports the eduGAIN Entities Database (eduGAIN-ED), login, tools offerings, service request and fulfilment through the separately orchestrated, cloud-based, user-designated service instances [[eduGAIN-ED](#)].

The system itself is designed to be able to accept any tool integration, not just from the network management portfolio. The tools can come from the NREN community as well, as is the case with the NAV tool developed and supported by Uninett [[NAV](#)].

Within the NMaaS production service, the support will be provided to end users that will use the NMaaS system in the everyday management of their infrastructure. The support will also be provided to the users that will offer their tools via NMaaS system, in the form of the initial integration and further maintenance via the system.

1.2 Service Description

The NMaaS service includes two main components:

- Providing, managing and maintaining the infrastructure of the NMaaS system (platform, portal and selected tools).
- Providing support to users.

User support can be categorised in two groups:

- Supporting use of the NMaaS system.
- Supporting users in contributing their software to NMaaS.

As such, providing the NMaaS service requires several types of experts to support the service.

The NMaaS service is aimed at organisations that might not have the required resources, skills and expertise to run a network management system, but have the need to monitor and manage network equipment. In addition, some institutions might have infrastructure sets that they should manage separately from some other equipment sets. Without NMaaS, such use cases would ask for stand-alone network management systems or outsourcing of management tasks, which again require human and financial resources.

The NMaaS system can be deployed centrally (in the GÉANT infrastructure) but can also be run by particular NRENs on their premises. The second option is particularly suitable for institutions that have

a need for multiple, network management tool instances themselves and/or would like to offer NMaaS service to their users (assuming they have required expertise and resources).

1.3 Service Benefits

NMaaS provides multiple benefits, as a system, an application marketplace, and as a service. NMaaS simplifies domain network management by providing the infrastructure and tools via a cloud-based, multi-tenant and secure network management system. It enables management and monitoring of client networks through on-demand deployment of network management tools in the cloud infrastructure.

Initially, the NMaaS service offers a set of selected tools for network management. This set can be extended with other tools, including the tools that might be developed in NRENs and that NRENs are willing to make available to others via NMaaS system and share within the community. The list of tools does not have to be limited to network management.

The tools are installed on NMaaS infrastructure in the cloud, which is then accessed within a dedicated virtual private network instance. The NMaaS setup requires minimum configuration inputs from users, thus removing the obstacles for the prerequisites needed from users in order to be able to start using the service.

With NMaaS, users do not have the ownership of specific costs and risks for network management infrastructure maintenance and management. This makes NMaaS a suitable service, in case one wants to delegate the network management task. An NMaaS instance can be created to manage a part of the infrastructure, and the task of monitoring and maintenance of this equipment can then be assigned to a designated team. The team is then able to focus on the infrastructure management, without the need to manage and maintain the underlying infrastructure of the network management system.

2 Service Users

NMaaS users are organisations that do not want to own NMS infrastructure themselves and/or want to outsource network management, as well as organisations and/or individuals that are searching for quality network management software or who want to share their software within the community.

Three user groups can be recognised:

- Small or emerging NRENs.
- Small organisations.
- GÉANT community users interested in sharing the software via NMaaS.

The following subchapters represent the three user groups and individual use cases.

2.1 Small or Emerging NRENs

Small or emerging NRENs might have limited resources, either with the number of employees or with the skills and knowledge needed for establishing and managing a network monitoring and management system. Apart from the human resources needed, such task would also require acquiring the physical (reliable, redundant) infrastructure, integration of individual software components, possibly also purchasing commercial solutions. In all, the alternative to NMaaS is demanding in time, as well as human and financial resources.

In this use case, such NRENs would use NMaaS to monitor their own network assets. Depending on the technical capabilities of the NREN, an NMaaS system would be installed on their own infrastructure, or alternatively, an instance of the NMaaS system used to run on a central GÉANT resource.

2.2 Small Organisations

Small organisations can be schools, universities and projects which might not have the skilled staff and appropriate infrastructure to setup the system for monitoring their equipment set. Such organisations might be member organisations of an NREN, and that NREN might decide to support the organisation in managing their equipment via NMaaS, or an organisation might decide to use NMaaS itself.

In such a case, there are several options:

- An NREN installs NMaaS itself and use this to provide the service to small organisations of its interest; monitoring and fault alerting management could be the responsibility of staff, either at the NREN or small organisation.
- An NREN uses a centralised solution for individual organisational use cases.
- An organisation is using a central GÉANT NMaaS solution.

The activation of an option depends on an organisation preference.

2.3 GÉANT Community

The NMaaS application marketplace (the portal) offers applications integrated with the NMaaS system by the NMaaS T5 team – designers and developers – based on the most useful tools (initially based on a survey of tools used in NOCs in the GÉANT community). When users log on to the portal, they select a tool that is needed and then:

- An NMaaS infrastructure instance is created for the user.
- The selected application is installed on this infrastructure instance.

However, the marketplace is more than just a catalogue. GÉANT NRENs and the GÉANT community are a great source of different software that is currently not consistently organised or provided to the community. In case there is a wish to promote such software products, the NMaaS application

marketplace can serve the purpose. In addition, the NMaaS application marketplace can be seen by individuals from the GÉANT community as an opportunity to offer their own software.

Service users in this case would be organisations and individuals that want to offer and provide a support for their software development efforts.

3 Technical Description

NMaaS software enables users to choose the tool(s) that fit his/her needs the best and provides the ability to deploy selected tools in an automatic manner within a cloud infrastructure, including operations such as setting up a data communication network (DCN) for communication between the tool and the equipment to be managed/monitored in a customers' premises. Attention has been paid to ensure this deployment process very fast and straightforward for the user. This incorporates standard application packaging, configuration conventions, and DCN access models, and reduces the amount of information required from the user (for service/tool configuration) to the minimum.

NMaaS system provides the following main features:

- On-demand, automated deployment of network management tools/services via the platform catalogue that will be used by NRENs to manage their networks.
- Automated set up of secure connectivity between the deployed tools and client's infrastructure elements.
- Enable the client to administer these network management services.
- Enable the client to access collected data via a particular tool management user interface.
- Provide a number of ways to store sensitive, collected data in secure repositories.
- Enable a client/administrator to manage users (basic CRM functionality).

The NMaaS system relies mainly on two software components implemented from scratch within the project, third-party supporting applications and selected network management tools.

Two aspects are important for the understanding of NMaaS from the technical perspective: NMaaS architecture and NMaaS processes.

3.1 NMaaS Architecture

The NMaaS system includes the following components (Figure 3.1):

- NMaaS platform - core service application.
- NMaaS portal - web-based application marketplace.
- Virtualised infrastructure - cloud resources and DCN networks.
- Supporting software - tool image registry, file repository.
- Set of integrated tools.

Each of these components are presented in more details in the following sections.

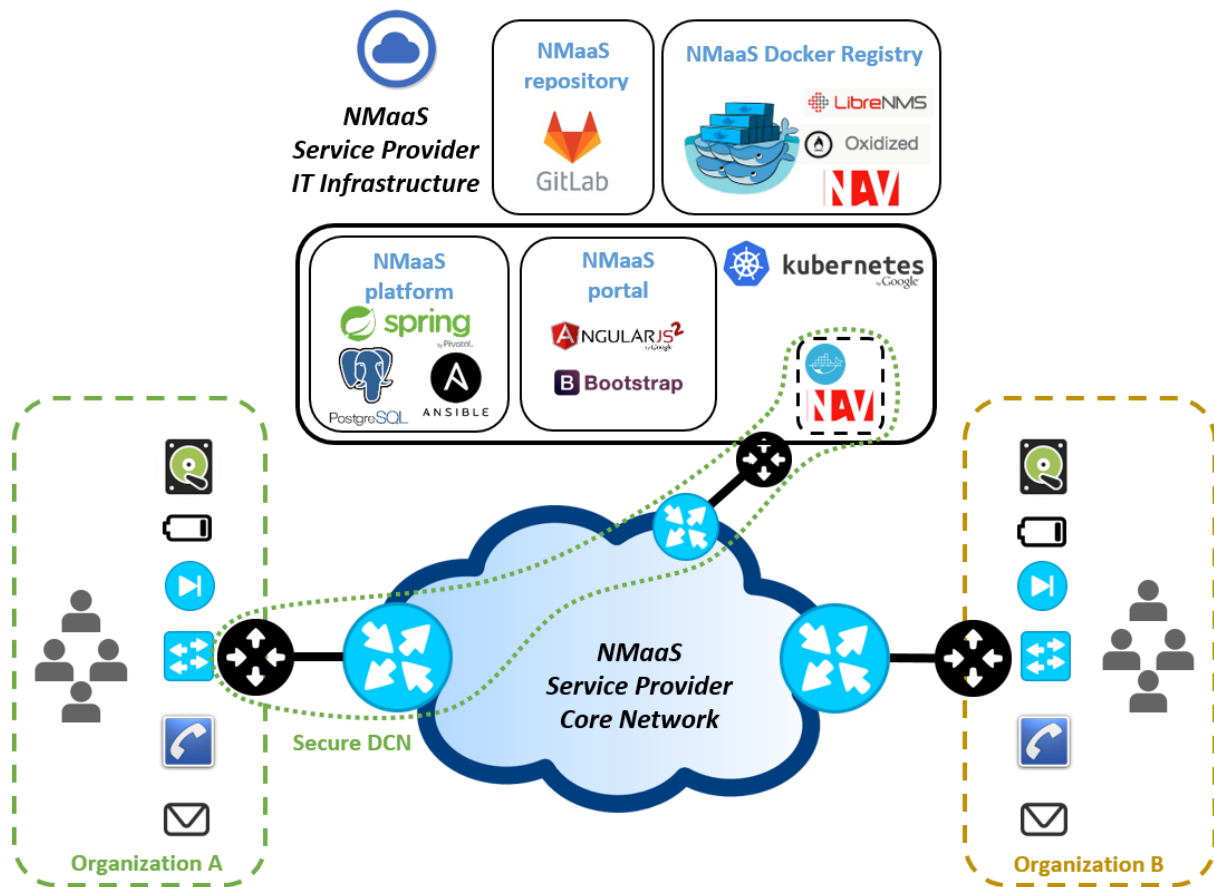


Figure 3.1: NMaaS system components

3.1.1 NMaaS Platform

The NMaaS platform is the core system software component that implements mechanisms for on-demand NM service deployment in the cloud environment and connectivity setup between the managed equipment and the running service. It is implemented as a Java Enterprise application based on the open source Spring Framework [Spring]. Application data is stored in a PostgreSQL database [PostgreSQL].

The NMaaS system relies on some third-party software instances to support the main processes triggered by the platform.

A community version of the GitLab repository instance is used to store the configuration files that are dynamically prepared and maintained for each of the NMaaS tool instances deployed in the cloud [GitLab]. Files are uploaded to the repository using the exposed REST API. Later in the process, Git commands are used to clone repositories and pull changes.

A dedicated instance of Docker image registry is deployed and used to store Docker images of integrated tools [Docker Registry].

Both GitLab repository and Docker registry can be deployed within the service provider IT infrastructure. The NMaaS platform itself may either be run on dedicated hardware or inside the Kubernetes cluster.

3.1.2 NMaaS Portal

Users interact with the NMaaS platform using the NMaaS portal – a web-based, front-end application presented in Figure 3.2. [Figure 3.1](#)

The NMaaS portal is a web front-end application developed with modern Angular2 and Bootstrap frameworks [[Angular2](#)], [[Bootstrap](#)]. It is a standalone component that uses the NMaaS platform REST API to load data, which is later presented to the user (e.g. regarding available applications, running application instances) and trigger actions in the system.

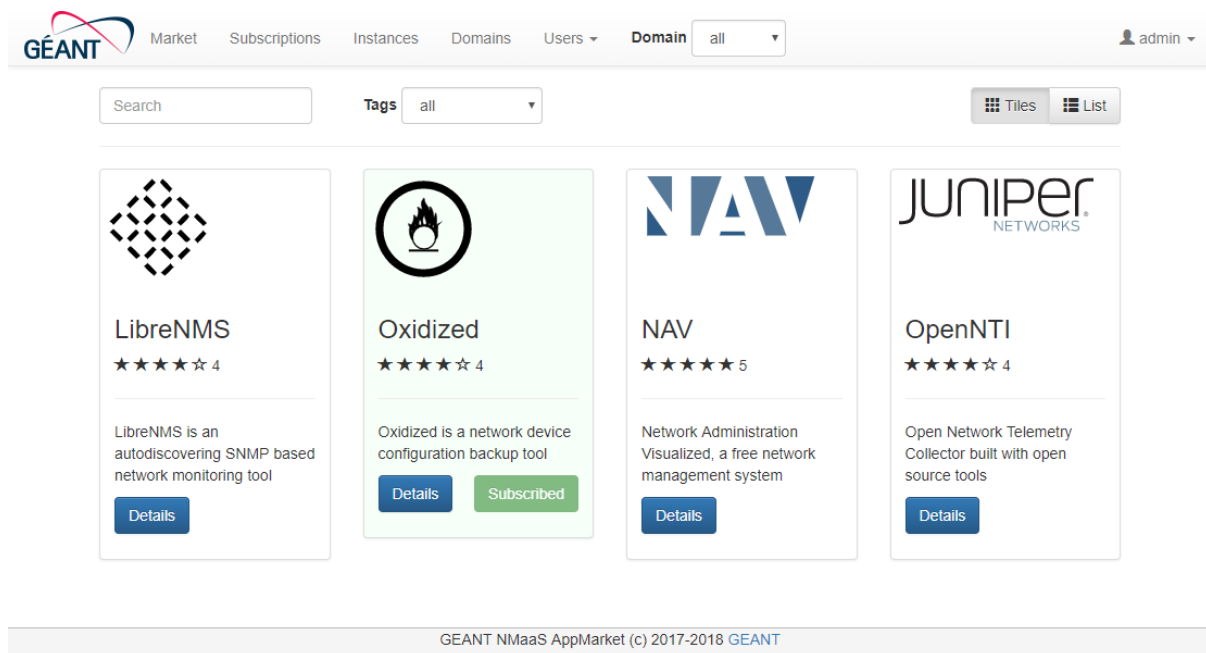


Figure 3.2: NMaaS portal tools view

Access to the portal is restricted to authorised users only. After a successful log in, the user is presented with a number of views and is able to perform a set of actions, depending on the granted roles (see Section 3.2.1 for further details on the concept of roles, domains and permissions).

A user with basic access is able to browse through all tools available in the marketplace, to view a tool’s details (including other user opinions) and provide his/her own ratings and comments. Any user granted a specific role within a domain in the system is enabled to trigger instance deployments of tools subscribed for this domain.

In addition, the NMaaS portal includes an administrator panel to be used by system admins and the Operations team to manage information about tools, domains and users.

3.1.3 Virtualisation in NMaaS

Cloud virtualisation

The cloud virtualisation approach followed by the project has evolved during the development of NMaaS. From the beginning, the approach for tool deployment on dedicated virtual machines was dropped in favour of the light virtualisation, based on containers [[Container](#)]. An initial option for tool deployment in the cloud considered Docker container deployment on bare-metal servers. Docker container deployments were to be triggered automatically by the NMaaS platform using the Docker Remote API [[Docker Remote API](#)]. Since managing container instances one by one is not feasible in real life deployments, the NMaaS platform was extended with support for Docker Compose mechanism [[Docker Compose](#)]. This allowed for deployment of complex services composed of multiple interacting containers in one command invocation. Docker Compose service deployment details are written down in YAML files (typically named `docker-compose.yml`).

Docker Compose was used for service deployment on one of the available Docker Hosts (servers or virtual machines on which the Docker daemon is running) configured to work with the system. This approach had a number of drawbacks, however, including issues with scalability or resiliency to server failure. For the pilot and production NMaaS tool deployments, the NMaaS system relies on Kubernetes, an open source system for managing containerized applications across multiple hosts, providing basic mechanisms for deployment, maintenance, and scaling of applications. Tool deployment in the Kubernetes cluster is done by remote invocation of Helm package manager commands [[Kubernetes](#)], [[Helm](#)]. For each of the integrated tools, a Chart file - application deployment description for Helm - was prepared. Additional Kubernetes cluster management and configuration tasks are performed by the NMaaS platform through the Kubernetes REST API [[Kubernetes REST](#)].

Network virtualisation and automation

In order to enable effective monitoring of the customer network, a Data Communication Network must be deployed. In a nutshell, this DCN is a VPN that can be implemented in various ways. It enables the connectivity between network management tools deployed in the Kubernetes cluster and the network elements to be supervised in the customer network domain.

It is assumed that a physical connection is already in place between the NMaaS Service provider, which is typically the case in the GÉANT/NREN context or NREN/NREN users, which are mostly universities and research institutions.

This DCN creation is integrated into NMaaS platform and is a key step of the network monitoring service deployment workflow. This is not set in stone, but one NMaaS DCN has been estimated per domain. Meaning that all the tools subscribed by the customer will exchange traffic via the same DCN.

The NMaaS platform proposes a framework to automate this DCN configuration if network automation is already in place in the service provider's organisation. If not, the NMaaS platform will

still be able to provide automated network configuration related to this DCN deployment that can be applied following the network change management process already in place.

The ideal scenario is the case where the first service deployment upon subscription is fully automated. However, this may not be possible in all network contexts. In any case, once the domain's NMaaS DCN is configured, subsequent service deployment will be fully automated upon subscription via the portal.

Network configuration automated generation is ensured by using YANG models, that get information from existing information database. Once populated, this YANG models can be used to generate DCN configuration stanza on all the service provider equipment.

These configuration stanza, can be manually deployed or automated using tools like Ansible playbooks. Tools like NAPALM can also be used in multi-vendor environment [NAPALM]. As network automation technology is moving fast, there is now also the possibility to directly configure the network equipment using the YANG model.

3.1.4 NMaaS Tools

The NMaaS system initially offers a set of four tools for deployment based on results of a survey carried out among NRENS to collect information on most commonly used tools for network equipment management and monitoring. Those tools were used during the GN4-2 to test the proper integration of the system.

Each tool, in order to be integrated with the system, needs to meet some requirements. Primarily, it needs to be released in the form of a Docker image and, depending on the deployment environment, either supported by Docker Compose or Helm, needs to provide appropriate deployment description files (e.g. docker-compose.yml or Helm chart). Those files need to conform to a set of rules set by the system concerning, e.g. the container initialization process, persistence storage and networking.

Furthermore, with each integrated tool, a set of configuration file templates needs to be provided. During new tool instance deployment these templates are populated with data provided by the user through the portal configuration wizard (e.g. list of IP addresses of devices to be monitored) to form final configuration files later used by the deployed instance.

Oxidized

Oxidized is a simple open-source device configuration backup tool exposing a web-based GUI [[Oxidized](#)]. Oxidized is packaged and deployed as a single Docker container and was used for system validation throughout the development and integration process. An official version of Oxidized Docker image is publicly available from the Docker Hub repository [[Docker](#)].

LibreNMS

LibreNMS is an auto-discovering PHP/MySQL/SNMP based network monitoring system which includes support for a wide range of network hardware and operating systems, including: Cisco, Linux, FreeBSD, Juniper, Brocade, Foundry, HP and many more [[LibreNMS](#)]. In addition to automatic discovery, its main

features also include: customisable alerting, API access, billing system, automatic updates and distributed polling. This tool is developed as a part of an open-source community-based project [[LibreNMSGitHub](#)]. Some Docker images for LibreNMS are already available and were used to build a custom image that supports the NMaaS container initialisation process. Moreover, new deployment descriptor files were prepared comprising instantiation of two containers for LibreNMS itself and a MySQL database on which the application depends.

NAV

Network Administration Visualized (NAV) is an advanced software suite to monitor large computer networks [[NAV](#)]. It automatically discovers network topology, monitors network load and outages, and can send alerts on network events by e-mail and SMS, allowing for flexible configuration of alert profiles.

NAV is an open-source software developed and maintained by UNINETT [[NAVGitHub](#)]. NAV instance deployment is complex in terms of the number of interacting service components (Docker containers). NMaaS uses already existing images published on Docker Hub together with customised deployment files.

OpenNTI

Open Network Telemetry Collector (OpenNTI) is an open-source container packaged with all tools needed to collect and visualise time series data from network devices [[OpenNTI](#)]. Data can be collected from different sources:

- Data Collection Agent – collect data on devices using CLI/Shell or NETCONF.
- Data Streaming Collector – can take all data streamed by Juniper devices as Input (JTI, Analyticsd, soon Openconfig with gRPC).
- Statsd interface – accept any Statsd packets. It is pre-configured with all tools and with a default dashboard.

Integration of OpenNTI with NMaaS required some significant effort since the application itself was still under development.

3.2 NMaaS User Roles and Processes

Any data load request and action triggered in the NMaaS system needs to be authorised. Users with appropriate permissions are enabled to trigger and/or take part in a set of defined NMaaS processes.

3.2.1 NMaaS User Roles

The implemented authorisation mechanism is based on the concept of domains and a well-defined set of user roles.

A domain in the system corresponds to a NMaaS customer - the institution connected to the NMaaS service provider network that uses the NMaaS system to deploy tools for monitoring its network devices. Most of the roles are assigned on a per domain basis.

There are several NMaaS user roles defined in the system, each of which allowing to perform clearly defined functions in the system. A summary of the roles with main actions allowed in the system is the following:

- GUEST - browse the global list of offered tools and view their details.
- USER - (within particular domain) view subscribed tools and deployed tool instances, trigger new subscribed tool instance deployment.
- DOMAIN_ADMIN - (within particular domain) manage users, subscribe tools.
- TOOL_MANAGER - introduce new tools to the system.
- SUPERADMIN - globally manage domains, users and tools.

Users create accounts in the system using a registration form in the NMaaS portal. During registration, a user can select a domain s/he wants to be assigned to. The account creation requests are approved either by DOMAIN_ADMIN (only for users within his/her domain) or SUPERADMIN. One person can have one or more of the described roles.

3.2.2 NMaaS Subscription and Deployment Process

A typical NMaaS tool subscription, deployment and configuration workflow comprises the following steps:

1. User logs in on the main NMaaS portal webpage.
2. User browses the catalogue of currently offered/supported tools.
3. User (DOMAIN_ADMIN role required) selects the tool s/he wishes to subscribe (e.g. an SNMP poller to gain admin and operational status for node interfaces). A tool subscribed in a domain can later be instantiated by any user belonging to that domain.
4. User (USER role required) selects and requests instantiation of a tool available in his domain.
5. NMaaS platform executes a series of actions, e.g. validates request, configures a secure VPN.
6. Once the deployment preparation process is completed, the user is redirected to a simple configuration wizard specific for each tool.
7. User provides basic configuration data (e.g. IP addresses) about the network equipment s/he wishes to manage with the selected tool.
8. NMaaS platform generates tool configuration files according to the user provided data.
9. NMaaS software deploys a new, pre-configured instance of the selected tool dedicated for the user in the cloud.
10. User logs in to the tool management interface via a URL dynamically generated by NMaaS and has access to the collected monitoring/management data.

The whole process lasts for only a few minutes and the user can follow this process execution through a status bar that is presented on the portal. On this way, the user can follow the process himself. After the process is completed, the user can start to use the service immediately.

4 Service Operations

Operations of the NMaaS service requires establishment of the core infrastructure: production instance of service portal, platform with the underlying infrastructure and tools, and the orchestration process. It requires definition of operations and support teams, service policies, and the service metrics, according to which the service will be evaluated and its success assessed. The operational aspects described in this section form part of the service definition and will be put in place with the service in production.

4.1 Supporting Infrastructure

Based on the service architecture and technical description presented in the previous chapter, the following supporting infrastructure is needed for NMaaS service:

- Monitoring system for checking the health of systems and services and raising alarms.
- Systems and service operations framework for service deployment and orchestration.
- Issue-tracking system for operational issues.

All these components will be established, validated and tested before the service transitions into production.

4.2 Operations and Support Teams

Operations of the NMaaS production service will be handled by the GÉANT Operations team. Together with managing and maintaining the production infrastructure, the GÉANT User Support team will provide the first level support to the users. The Developers' team in GN4-2's Joint Research Activities will provide the second-level support.

There are three teams that support the NMaaS service:

- GÉANT Operations, which takes care of the service in production, i.e. manages and maintains the installed infrastructure as well as providing support for the users. It will be available at nmaas-ops@lists.geant.org.
- Business Development and Service Management, which tracks the usage of the established service, gathers feedback and input from the user groups and actively takes part in the future-service roadmaps. The team's focus is on potential and new users. The team can be reached at nmaas-team@lists.geant.org.

- NMaaS Developers, which translates the input from the operations, business development and service management teams into future software and service versions. The team can be reached at nmaas-dev@lists.geant.org, primarily for technical and implementation-specific topics.

4.3 Service Policies

The NMaaS service is not limited to a particular user group. However, with its execution within GÉANT project, the NMaaS service primarily targets the GÉANT community and all users that can access through eduGAIN.

4.4 Service Metrics

Metrics of NMaaS service are designed so that they assess the quality of the provided service, as well as the service usage.

Quality of the provided service is assessed through the system availability. Therefore, the availability of the established infrastructure will be one key performance indicator (KPI), with the target value set to 99.9 %.

Service usage will be measured through the number of organisations that have registered for the service. Since the service will go into production closer to the project end, target value for this first period is set to 1.

5 Service Roadmap

In the remaining project period the focus is on the transition of the NMaaS v1.0 into production. The next software version - NMaaS v2.0 will consider enhancements to the system including among others an option for upgrading already deployed tools to latest versions or a user-friendly graphical interface for adding new tools to the NMaaS portfolio. The future development might also include extensions of the NMaaS marketplace concept towards the tools outside of the network management area. The development of the next version will start during this project period, while the transition into production targets a later period.

6 Conclusions

Network Management as a Service is a new development of the GN4-2 project. NMaaS aims to assist network engineers in managing and maintaining the network infrastructure through the tools provided within NMaaS service. This way, users can focus on the network management tasks without undertaking the specific costs and risks of managing the underlying infrastructure themselves.

Other benefits of NMaaS Include:

- NMaaS simplifies domain network management by providing the infrastructure and tools via a cloud-based, multi-tenant and secure network management system.
- It enables the deployment of network management tools, as well as management and monitoring of client networks.
- The selection of tools that is and/or can be made available to users is not limited to network management tools and can be easily extended.
- Users do not have to bear the ownership of costs and risks related to maintenance and control of the network management infrastructure.

The NMaaS service transitions from development into production, and the transition process includes the preparation of the production infrastructure, as well as the establishment of the Operations and Support teams.

This document provided a detailed description of the NMaaS Production Service, its service elements and technical aspects, as well as the explanation of the service support levels, policies, metrics and a roadmap for future development.

References

[Angular2]	https://angular.io/
[Bootstrap]	https://getbootstrap.com/
[Container]	https://www.docker.com/what-container
[Docker]	https://hub.docker.com/r/oxidized/oxidized/
[Docker_Compose]	https://docs.docker.com/compose/
[Docker_Registry]	https://docs.docker.com/registry/
[Docker_Remote_API]	https://docs.docker.com/develop/sdk/
[eduGAIN-ED]	https://technical.edugain.org/entities
[GitLab]	https://gitlab.com/gitlab-org/gitlab-ce
[GN4-2]	https://www.geant.org/Projects/GEANT_Project_GN4
[Helm]	https://helm.sh/
[Kubernetes]	https://kubernetes.io/
[Kubernetes_REST]	https://kubernetes.io/docs/reference/api-overview/
[LibreNMS]	https://www.librenms.org/
[LibreNMSGitHub]	https://github.com/librenms/librenms
[NAPALM]	https://napalm.readthedocs.io/en/latest/
[NAV]	https://nav.uninett.no/
[NAVGitHub]	https://github.com/UNINETT/nav
[OpenNTI]	https://github.com/Juniper/open-nti
[Oxidized]	https://github.com/ytti/oxidized
[PostgreSQL]	https://www.postgresql.org/
[Spring]	https://spring.io/

Glossary

CRM	Customer Relationship Management
DCN	Data Communication Network
GUI	Graphical User Interface
JRA	Joint Research Activity
KPI	Key Performance Indicator
NAV	Network Administration Visualized
NMaaS	Network Management as a Service
NREN	National Research and Education Network
OpenNTI	Open Network Telemetry Collector
VPN	Virtual Private Network