16-03-2022

Deliverable D6.8
Network Management and Monitoring Services

Deliverable D6.8

Contractual Date:	31-03-2022
Actual Date:	16-03-2022
Grant Agreement No.:	856726
Work Package	WP6
Task Item:	Task 3
Nature of Deliverable:	R (Report)
Dissemination Level:	PU (Public)
Lead Partner:	UoB/AMRES
Document ID:	GN4-3-22-0BDE97
Authors:	Pavle Vuletić (UoB/AMRES), Antoine Delvaux (PSNC), Szymon Trocha (PSNC), Łukasz Łopatowski (PSNC), Ivana Golub (PSNC), Tim Chown (Jisc)

Abstract
The Monitoring and Management Task (Task 3) of the Network Technologies and Services Development Work Package (WP6) in the GN4-3 project takes care of several network monitoring and management services in production, including the newly launched WiFiMon service, and has continued the relevant developments from the GN4-2 project. This document presents the network management and monitoring service portfolio after three years of the GN4-3 project, as well as an overview of ongoing earlier-lifecycle work and activities that were initiated in this project phase.

Table of Contents

Table of Figures

Table of Tables

Executive Summary

The Monitoring and Management Task (Task 3) of the Network Technologies and Services Development Work Package (WP6) in the GÉANT Network 4 Phase 3 (GN4-3) project is responsible for several production network monitoring and management services, i.e., perfSONAR, perfSONAR Consultancy and Expertise, Network Management as a Service (NMaaS), the Performance Measurement Platform (PMP) and WiFiMon. WP6 T3 is also exploring some earlier-lifecycle novel monitoring and network management mechanisms, such as alarm correlation, the methods to monitor high-speed (100G) network paths, advanced monitoring data analytics and the use of programmable network elements for advanced monitoring applications. In addition, the WP6 Network Technology Evolution Task (Task 1) is exploring a per-segment latency and jitter measurement tool and the use of In-band Network Telemetry (INT). All the above services are aimed at the GÉANT community at large.

This document presents the network management and monitoring service portfolio after three years of the project, together with ongoing work and new initiatives in this project phase by WP6 Task 3 and Task 1. It can be used as a report of the service status for WP6 Task 3 and for comparison with the status of the services at the beginning of the project, summarised in Deliverable D6.1 *Network Management and Monitoring Portfolio* [D6.1].

As a summary of the presented work, all the production services have met or exceeded their key performance indicator targets. Overall, the portfolio of network management and monitoring services continues to fulfil GÉANT's objective of ensuring that the services it offers are current, effective, address real NREN demands and are well used.

1   Introduction

In the GN4-3 project's Network Technologies and Services Development Work Package (WP6), the Monitoring and Management Task (Task 3) works on the further development and evolution of network monitoring and management tools and services for the GÉANT community.

Task 3 inherited several in-production services from the previous project (GN4-2), as well as the ongoing development of some tools and services that are still in the earlier phases of their lifecycle. The services that entered their production phase before the GN4-3 project started are perfSONAR, perfSONAR Consultancy and Expertise, Network Management as a Service (NMaaS) and the Performance Measurement Platform (PMP). Another two tools that were piloted and tested successfully in real network environments during GN4-2 are WiFiMon and NetMon. During the second year of GN4-3, WiFiMon passed all the Product Lifecycle Management (PLM) gates and became a production service, while NetMon development was stopped in the first year of GN4-3 due to a lack of interest from the National Research and Education Network (NREN) community.

Five services are supported by the WP6 Task 3 team at the time of writing this document:

- **perfSONAR International Project** – perfSONAR software development and user support within the international collaboration with ESnet, Internet2, Indiana University, RNP and the University of Michigan.
- **perfSONAR Consultancy and Expertise** – supporting the GÉANT community in deploying perfSONAR in their environments, providing advice, training and support on designing and deploying a perfSONAR-based measurement architecture.
- **Network Management as a Service (NMaaS)** – provides a platform and a portfolio of network management and monitoring applications which are run as dedicated and isolated per-user instances in the cloud. NMaaS users are typically institutions that lack capacity to manage a network management platform themselves, but prefer to focus solely on the management and monitoring of their network operations.
- **Performance Measurement Platform (PMP)** – providing an open, trusted monitoring and measurement information infrastructure; this is currently based on perfSONAR but may in the future adopt additional tools.
- **WiFiMon** – WiFiMon is a hybrid crowd-sourced and/or hardware probe-based WiFi network monitoring and performance verification system capable of detecting performance issues, visualising the achievable throughput of a wireless network for each user, and providing technical information about a WiFi network.

In parallel with the operation and development of the above-mentioned production services and tools, Task 3 is developing an alarm aggregation tool called Argus [Argus], which is well-suited to support

the Campus Network Management as a Service (CNaaS) use case by aggregating all the alarms from various campuses managed by an NREN. Task 3 is also exploring the methodologies of doing monitoring tests on very high-speed network paths (100 Gbps), and the use of P4-capable network cards for achieving higher rates of unsampled network flow capturing compared to the off-the-shelf network elements, and analysing large amounts of historical measurement data gathered from the PMP measurement points and correlating this data with specific network events. Task 3 has also written a white paper on zero-footprint monitoring [WP_Zero], which is designed to be used as a cookbook for NRENs interested in deploying this type of technology, including the use of streaming telemetry for monitoring information gathering.

This document presents a snapshot of the status of the Task 3 network management and monitoring services after three years of the GN4-3 project. It focuses on those services and tools that are in production, and briefly presents other developments and potential services that are at an early stage of the service lifecycle, where their value and the demand for their development is being assessed. It also provides pointers to the work done in WP6 Task 1 Network Technology Evolution in two network monitoring areas, the first being the TimeMap per-segment jitter and latency monitoring platform that is deployed on the GÉANT backbone, the second being the use of In-band Network Telemetry (INT) on various forms of programmable network hardware. The document also supports and provides input to the management and monitoring services strategy for the Network Technologies and Services Development Work Package, drawing conclusions from the current use of and development demands for the existing portfolio, as well as looking at current developments and deployments in the participating organisations.

The document consists of two main parts: Section 2, which describes the current status of the services in production, covering users, uptake and usage, key performance indicators, and activities; and Section 3, which summarises the current status of other developments and tests at an earlier stage of their lifecycle that are performed in WP6 in T1 and T3.

2 Services in Production

This section describes the current status of the production services, namely:

- perfSONAR.
- perfSONAR Consultancy and Expertise.
- Network Management as a Service (NMaaS).
- Performance Measurement Platform (PMP).
- WiFiMon.

For each service it provides a high-level description; information on users, uptake and usage; key performance indicators; and activities.

2.1 perfSONAR International Project

perfSONAR is an open-source, modular and flexible architecture for active network performance monitoring that provides a view of network performance across multiple domains, allowing Network Operations Centre (NOC) or Performance Enhancement Response Team (PERT) engineers to analyse and diagnose network behaviour across an entire end-to-end path. The tools provided in the perfSONAR suite perform active measurements of throughput, packet loss, delays and jitter, and record network route and path changes. There is also provision for application-level measurements such as HTTP, DNS and disk-to-disk transfers.

The global perfSONAR team develops, maintains, distributes and provides support for the full perfSONAR tool suite that is installed and used on numerous Research and Education (R&E) networks around the world to perform active measurements and monitor network performance.

Public-facing information about the perfSONAR development and support provided by the GN4-3 project can be found online [perfSONAR_Wiki].

A number of information sources are available for the perfSONAR project:

- Main website [perfSONAR_Website].
- Installation and usage documentation [perfSONAR_Docs].
- Support requests can be submitted through the user mailing list using *perfsonar-user@internet2.edu* or webmail [perfSONAR_Webmail].
- Developers' resources are available on Git [perfSONAR_GitHub].

2.1.1 Users, Uptake and Usage

Active network measurements are useful to network engineers, system administrators, research communities, researchers and students. perfSONAR users include:

- Organisations (e.g. universities, GÉANT NRENs and GÉANT itself) that want to provide active network measurement capabilities to their users or to any collaborating organisation's users (enabling multi-domain measurement capabilities).
- Organisations that want to perform active measurements within their own domain or any other perfSONAR-enabled domain.
- Research communities that undertake data-intensive science, need to move large volumes of data between sites and want to have telemetry on network characteristics.
- Individual users who want to monitor end-to-end performance or performance on particular links of interest.
- Network researchers and students interested in developing or monitoring and assessing the performance of new high-speed networks, technologies and protocols.

perfSONAR users are located worldwide and form the global perfSONAR community. The map in Figure 2.1 shows a global subset of perfSONAR nodes registered in the central lookup service [perfSONAR_Usage]. There are also a number of private installations in addition to these 1,871 public nodes with 7,942 services implemented worldwide as of January 2022. The number of services depends on the perfSONAR version and on which services the users have activated.

Figure 2.1: perfSONAR installations worldwide

There are more than 400 perfSONAR deployments in European countries, including Armenia, Austria, Belarus, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Moldova, Montenegro, Netherlands, Norway,

Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Sweden, Switzerland, the United Kingdom and Ukraine.

2.1.2 Key Performance Indicators

The key performance indicator (KPI) for perfSONAR measures the number of major perfSONAR releases per year. Table 2.1 shows the current KPI value.

KPI	Target	Baseline	Measured
Number of major perfSONAR releases in 2021	1	1	1

Table 2.1: perfSONAR KPI measured for the period 01 January 2021 – 31 December 2021

The last major perfSONAR release, 4.4, was issued in July 2021. Recently, two minor releases were issued: perfSONAR 4.4.1 in August 2021 and 4.4.2 in January 2022. Version 4.3 was released in 2020 and 4.2 in 2019.

2.1.3 Activities

The work of the global perfSONAR team is currently focused on preparing the next major release of perfSONAR (version 5.0), which will bring a complete overhaul of the data storage backend. The GÉANT project team contributes to building, testing and fixing all Debian/Ubuntu packages, improving the user interface (UI), introducing a new graphical UI (GUI) for pScheduler, and testing and debugging perfSONAR 5.0. The team is also responsible for upgrading the whole Debian build and distribution infrastructure to the latest Debian and Ubuntu standards. perfSONAR minor release versions 4.4.1 and 4.4.2 focused on minor updates and bug fixes.

The GÉANT team also provides user support via the regular channels. Queries are mostly related to upgrades of existing installations and feedback about usage of new perfSONAR releases or, in the case of new users, regarding the perfSONAR installation and setup.

The GÉANT team also co-chairs training and documentation activities. Within the global project it coordinates and performs tasks relating to providing users with proper documentation and training resources, including maintaining the perfSONAR web pages and YouTube channel.

In the research and development area, work is being done by the team to look at perfSONAR usage or integration in projects such as the low latency monitoring system TimeMap, developed by WP6 T1, and WiFiMon.

The perfSONAR software suite has recently been presented as a part of the WP6 work at the following events:

- UK Network Operators' Forum meeting, 19 November 2021, remote, UK [UKNOF_48].
- PL-5G project consortium meeting, 30 November 2021, remote, Poland.

perfSONAR was also featured in Issue 38 of *CONNECT* [CONNECT_38], with a two-page article titled "perfSONAR, the ever evolving performance toolkit".

2.2 perfSONAR Consultancy and Expertise

perfSONAR Consultancy and Expertise aims to provide support and disseminate knowledge about perfSONAR usage for the GÉANT community. It offers four different activity types:

- Helping to ensure that designed measurement architectures and infrastructures based on perfSONAR fit the performance monitoring and measurement needs of the requesting party.
- Providing specific training and running workshops on perfSONAR deployment, usage and best practices.
- Providing extra support to assist GÉANT and NRENs with deploying and operating perfSONAR, as requested.
- Maintaining and operating a set of perfSONAR services useful to the global perfSONAR community and GÉANT-area perfSONAR users in particular.

Contact details for perfSONAR Consultancy and Expertise are available on the GÉANT wiki [perfSONARC&E_Wiki] and the team can be directly reached through perfsonar@lists.geant.org.

2.2.1 Users, Uptake and Usage

Target users of this service are teams and individuals from the GÉANT community. Since active network measurements and network performance monitoring require specific and advanced knowledge, users are mostly from Network Operating Centres (NOCs) or the NRENs' constituencies or cross-domain projects in which they might participate. However, the service's availability is not limited to a specific user group.

2.2.2 Key Performance Indicators

The key performance indicator for perfSONAR Consultancy and Expertise is the number of requests for consultancy that the team fulfils during the reporting period.

KPI	Target	Baseline	Measured
Number of requests for consultancy fulfilled	3	3	9

Table 2.2: perfSONAR Consultancy and Expertise KPI measured for the period 01 January 2021 – 31 December 2021

2.2.3 Activities

The perfSONAR Consultancy and Expertise service is currently providing support to:

- GÉANT, Jisc, SURF and the WLCG project to run 100 Gbps measurements on international and transatlantic links.
- The WiFiMon project to integrate perfSONAR and activate reliable measurements on WifiMon deployments.

As part of the service activities, the following consultancies have been closed during 2021:

- Jisc to discuss the perfSONAR trace visualisation options including the dedicated MaDDash grid.
- Uninett/Sikt to design a latency measurement architecture based on perfSONAR.
- HEAnet to troubleshoot and upgrade their main perfSONAR machine.
- ARNES, ASNET and RENATER to update their internal perfSONAR deployments.
- The LoLa low latency audio-visual streaming project to help measure latency and jitter between LoLa project sites.

The Consultancy and Expertise service has recently been presented as a part of the WP6 work at the following events:

- 23rd Service and Technology Forum, 6 July 2021, Online [STF_23].
- 24th Service and Technology Forum, 26 October 2021, Online [STF_24].

The team has also prepared and run the 2nd European perfSONAR User Workshop [perfSONAR_2UW], which brought together the perfSONAR user and developer communities to explore use cases for the toolkit, share best practices, and discuss future features and the perfSONAR development roadmap. The workshop was held online on 14–15 April 2021. Planning is underway at the time of writing to hold the 3rd European perfSONAR User Workshop in the spring or summer of 2022.

2.3   NMaaS

Network Management as a Service (NMaaS) provides a solution for on-demand deployment of Network Management Systems (NMSs) composed of various network monitoring and management tools on a highly available cloud-based platform. Using a web-based NMaaS portal, users are able to create secure and isolated containerised environments with a selection of installed tools tailored to their needs. In this way, they can focus solely on the management of the infrastructures they are responsible for, instead of taking care of the NMS platform itself.

Establishing an NMS requires complex, reliable and usually costly infrastructure, with skilled and knowledgeable experts who need to maintain the underlying platform and associated tools. With NMaaS, users do not have to find the resource and bear the costs and risks associated with setting up and maintaining the network management infrastructure; instead they can just focus on using the provided tools.

The NMaaS service includes three aspects:

- Providing, managing and maintaining the infrastructure of the portal, platform and selected tools.

- Supporting users who want to monitor and manage their infrastructure using the NMaaS platform and selected tools.
- Supporting users in contributing and adding their applications to the NMaaS platform portal. The NMaaS team ultimately decides which tools will be offered via the platform and supports contributors in providing their software via the platform.

The GÉANT project offers NMaaS in two forms:

- Developing and maintaining the NMaaS software for organisations (usually NRENs) that wish to install an NMaaS instance on their own network for their users, and providing support for those organisations.
- Providing a central NMaaS installation available at [NMaaS], managed and operated by the WP6 Task 3 NMaaS team.

NMaaS has been a production service in the GÉANT project service portfolio since December 2018.

2.3.1   Users, Uptake and Usage

NMaaS is offered primarily to the GÉANT community with the intention to support small and emerging NRENs, small organisations, distributed research projects and GÉANT project teams that:

- Do not want or do not have the capacity to operate a full NMS infrastructure themselves.
- Plan to outsource network management activities.
- Look for quality network management software.
- Want to share their software with the community.

There are two instances of NMaaS: a sandbox instance provided by the GÉANT organisation, and the central hosting instance provided by PSNC. In addition, two proof of concept installations were deployed by RENATER (who have recently upgraded their cluster) and Sikt.

In cases where an NREN or project foresees that it will need to serve multiple customers on its own or run multiple monitoring applications, and have full control over their instance, the preferred approach is a dedicated instance of NMaaS deployed on that NREN's premises.

During the course of the project, the NMaaS team has been actively disseminating information about the service and encouraging potential users to set up their monitoring solutions using NMaaS. These activities were performed through a number of presentations and demonstrations during infoshares and conferences hosted by both the GÉANT project and particular NRENs. Additional meetings were conducted with interested institutions to provide detailed information on NMaaS and use cases it addresses.

At the time of writing this report, the central NMaaS hosting instance is used by:

- GÉANT and NRENs: CyNet, HEAnet, ARNES, RENATER, SURF, GARR and PIONIER (PSNC).
- NREN end institutions from Slovenia, Spain, Germany, Serbia, Italy and Ireland.

- NREN representatives in GÉANT project teams: RARE (WP6 T1), PMP (WP6 T3), perfSONAR development (WP6 T3) and WiFiMon (WP6 T3).

In addition, a standalone NMaaS instance was deployed by a team from Northwestern University (USA).

2.3.2 Key Performance Indicators

The NMaaS software stack has been continuously enhanced in order to address recognised improvement opportunities and feature requests originating from the NMaaS users. New developments eased the installation process and operation of the software to improve user experience.

New tools were integrated with NMaaS as the project progressed to enhance the offer for the existing and new users. This effort was and is considered a crucial factor to achieve greater service adoption. The tools were selected based on direct user feedback and popularity among NRENs.

The availability of the NMaaS platform has been monitored and measured by an external service UptimeRobot [UptimeRobot]. Two events had the most impact on the NMaaS availability statistics during the reported period. In February 2021 one of the main network switches providing Internet connectivity to the NMaaS production cluster failed due to an unexpected power outage and had to be replaced. The NMaaS service was also affected by a PSNC-wide connectivity issue in July 2021.

KPI	Target	Baseline (01-01-2021)	Measured (31-12-2021)
Number of releases in production per year[1]	1	3	1
Number of tools added to the portfolio per year in response to customer demand[2]	2	14	5
NMaaS platform availability	99%	99.31%	99.86%
NMaaS service uptake per year (deployed on GÉANT or NREN instances)	2	13[3]	6

Table 2.3: NMaaS KPIs measured for the period 01 January 2021 – 31 December 2021

Notes:

1. NMaaS had four major releases within the GN4-3 project by the end of 2020 (considered as the baseline) and one major release in January 2021.
2. NMaaS had fourteen tools added to the portfolio within the GN4-3 project by the end of 2020 (considered as the baseline) and an additional five tools added in 2021.
3. Number comprises user domains created on NMaaS central service by GÉANT, NRENs, institutions and GN4-3 project teams by the end of 2020.

2.3.3 Activities

The activities carried out by the NMaaS team since the beginning of the project were focused on three major areas:

- Maintenance and further enhancement of the NMaaS central instance infrastructure.
- Supporting current service users and proactive engagement of new users.
- Further development of the NMaaS software components and addition of new tools to the NMaaS catalogue.

During the first months of the project the team deployed a new NMaaS production service on a bare-metal hardware infrastructure in PSNC (available at [NMaaS]), which provides the NMaaS team with direct and full control over the underlying infrastructure hosting the service. PSNC has delivered a sufficient number of servers and storage space to meet the current and foreseen future demand from the NMaaS users. The instance in GÉANT thus became a sandbox NMaaS instance and is available at [NMaaS_Sandbox].

In order to secure the monitoring data transfer between the tools running on the NMaaS central infrastructure and the equipment located in user premises, two VPN solutions are supported by the platform. First, support for OpenVPN [OpenVPN] software-based VPNs was added, and later WireGuard [WireGuard] was integrated, as it uses novel cryptographic algorithms and provides better performance (in terms of throughput). Both solutions will continue to be supported to allow users to choose the one most suitable in their context.

Software development activities were focused on further improvements of the user tools installation and configuration processes. A production-ready version of the NMaaS Helm chart was published and a comprehensive NMaaS Installation Guide prepared, to allow users to easily deploy instances of NMaaS on top of their own existing Kubernetes-based infrastructures [NMaaS_IG]. Support was added for a GitOps-based application configuration model so that users can update the configuration of their running application instances through applying changes in configuration files stored in dedicated Git repositories. A number of implementation enhancements were applied to allow for extending the NMaaS catalogue with new tools. In order to ease further software maintenance and ensure IPR compliance, automatic WhiteSource scanning was performed in collaboration with the Operations Support Work Package (WP9) software audit team.

Throughout the project, NMaaS has been actively promoted and demonstrated at various events organised by the project (e.g. the GÉANT Symposium in 2020 ([GNSym_2020], [NMaaS_GNSym2020]), TNC21 [TNC21], the Workshops on Network Management and Monitoring in 2019 and 2021 ([Workshop_NMM], [NMaaS_WorkshopNMM]; [Workshop_NMMT]), STF in 2019 and 2020 ([STF_18], [NMaaS_STF18]; [STF_21], [NMaaS_STF21]), NREN conferences (e.g. ACOnet Workshop in 2020, Jisc Networkshop in 2021 [Jisc_Networkshop49] and the GARR Workshop in 2021 [GARR_Workshop]) and infoshares, including the one dedicated to NMaaS organised in November 2020 [Infoshare_NMaaS].

2.4 PMP

The Performance Measurement Platform (PMP) is set up as an open, trusted monitoring and measurement information infrastructure, provided to network engineers, NOC operators, research communities, network researchers and NREN participants to monitor, explore, practise and learn how network performance monitoring can contribute to better and more efficient usage and understanding of the existing multi-domain network infrastructure. It supports GÉANT's strategy in maintaining GÉANT's position as a provider of infrastructure services, organising the whole ecosystem of service delivery from NRENs to other NRENs, as well as in supporting collaborative efforts to innovate the service portfolio and create advanced services.

The Performance Measurement Platform includes 50 distributed measurement points with pre-installed perfSONAR. It thus extends the perfSONAR footprint in Europe and beyond (for example, to Ghana, Nigeria and Senegal) and enables, from an NREN's perspective, better visibility of the performance of the established GÉANT network infrastructure. PMP is also changing the perspective of how perfSONAR measurement points are designed and deployed – from standalone servers to cheaper, readily available and readily configurable small boxes.

The small nodes perform regular measurements towards a few perfSONAR Measurement Points (MPs) located in the core of the GÉANT network and operated by the GÉANT Network Operations Centre. In late 2021, these tests were extended to include several MPs worldwide that correspond to intercontinental GÉANT network connectivity, e.g. via BELLA to South America and TEIN to Asia.

The central components that manage the platform elements and gather, store and represent the performance data are operated and maintained by WP6 Task 3. The project team has also implemented automation (using Ansible) to address maintenance routines and replace sequences of manual tasks. PMP small-node users can modify the predefined setup by configuring additional measurements to their needs, and in so doing become more familiar with the platform.

2.4.1 Users, Uptake and Usage

PMP has three user groups:

- NRENs (or associated organisations and universities within an NREN) that are hosting a node and thus participate in a PMP mesh, setting up measurements of interest and using the PMP measurement results for their own benefit.
- End-user institutions or communities that are not hosting a node but use the measurement results that are publicly available via the PMP dashboard.
- Individuals or organisations that are implementing the PMP model and the software to install their own public or private measurement mesh.

Nodes provided by the project are distributed primarily to NRENs, but also to end-user organisations willing to host the node and to institutions partnering with the GN4-3 project. Some of the nodes are used for research and development as well as for testing purposes by the PMP service team. Independently of their hosting organisation, all nodes are managed by the PMP team in WP6 Task 3.

The third group procures and manages their nodes themselves. This also includes organisations that have started with a single PMP node provided by the project and then extended the footprint of perfSONAR nodes in their domains based on this initial deployment. Example countries are Belarus (deployment for the EaPConnect project), Poland and the UK. Some have also established PMP presence in a virtual environment (NORDUnet).

2.4.2 Key Performance Indicators

Critical success factors that can be used to measure the success of the PMP infrastructure are:

- Availability of the central infrastructure.
- The number of GÉANT project partner countries that host a small node in their network.
- User satisfaction.

Availability of the central infrastructure is measured based on the availability of the MaDDash (graphical user interface) and measurement archives. Availability measurements were only implemented at the beginning of the project, therefore existing baseline figures are not available. The measured availability between 1 January 2021 and 31 December 2021 was 100%, while the target availability is 99%.

Having as many GÉANT NRENs taking part in this project as possible is an important goal, therefore distributing the PMP nodes to GN4-3 project partners (NRENs) is the priority. However, it can be expected that due to limited resources some NRENs will currently not be interested in taking part. Also, for some countries more than one node is distributed. Additional nodes go to organisations particularly interested in hosting perfSONAR and using the infrastructure provided by GÉANT and the NRENs. Therefore, the total number of nodes distributed will be higher than the number of GN4-3 project partner countries (38). At the time of writing, a total of 50 nodes have been distributed amongst the PMP service participants, 45 of which went directly to GN4-3 project partners (NRENs). Five nodes are hosted amongst other interested organisations, institutions (GARNET/Ghana, NgREN/Nigeria, snRER/Senegal) or used as testing instances by the PMP service team (2 nodes). The KPI focuses on the geographical service coverage and counts just the number of countries seen as GN4-3 project partners. The target participation by the end of the project is 80% of the NREN project partner countries and it has already been reached (89%). The target value is not 100% as it can be expected that not all countries are willing or able to host a node.

User satisfaction is measured via a survey that is performed once a year among the participating organisations. Target satisfaction is at least 85% of users who rate their experience with the PMP service as good. Measuring how users describe the service allows the team to assess whether it meets the users' needs and provides high customer satisfaction. The user satisfaction survey for the year 2020 was issued at the beginning of 2021 and the survey for 2021 is planned later in 2022, after this document is published.

KPI	Target	Baseline	Measured
Availability of the central infrastructure	99%	N/A[1]	100%

KPI	Target	Baseline	Measured
The number of GÉANT project partner countries	80%	48%	89%
Overall user satisfaction	85%	N/A	92%

Table 2.4: PMP KPIs measured for the period 01 January 2021 – 31 December 2021

Notes:

1. The central infrastructure for the previous measurement mesh was provided using different platforms.

2.4.3 Activities

From the beginning of the project, the team has worked on the distribution of additional small nodes. Prior to COVID, this was usually organised in person during GÉANT-related meetings and conferences, together with dissemination activities. This distribution continued up to the beginning of 2020, when multiple new NRENs received their pre-configured nodes and connected them to the measurement mesh. Some of the institutions (FCCN, KIFÜ, PSNC) are also hosting a new PMP probe type based on the Raspberry Pi 4 device.

The team successfully transitioned all the existing small nodes to the new Performance Measurement Platform. This involved upgrading the PMP node to a new operating system, installing the latest version of perfSONAR and migrating (configuration update) to the new central infrastructure. Parts of the activities (upgrade of the operating system, installation of perfSONAR and restoring its configuration from backup) were done by the organisation hosting the probe. In addition, during further service operation, the team supervised several additional upgrades to the latest perfSONAR version – currently pS 4.4.2 running on CentOS7. The WP6 PMP team provided support to the hosting organisation during this process. In 2021 the PMP team also cooperated with the GÉANT IT team to reconfigure and align the PMP mesh configuration with the changing topology of GÉANT's perfSONAR nodes in the GÉANT network.

In 2021, the PMP mesh continued collecting the results of the new types of tests established in 2020. These were HTTP request type and DNS query time to measure application-specific parameters. Also, new intercontinental tests were added to the mesh to better reflect international traffic paths. These included tests towards North and South America, Asia and Japan.

The PMP service has a large database of recorded measurements. Since 2021, one part of the work within the PMP subtask has been research on the analysis of this historical data collected by the PMP service for more advanced data analytics and network trend predictions. The Esmond measurement database has a web API that enables these monitoring results to be accessed. Individual values and histograms of latency and jitter measurements are being normalised and analysed to establish a baseline and basis for future analysis and potential applications and conclusions that can be inferred from this large and rich dataset. The first results have been obtained and presented [PMP_DA], and this work will continue in Year 4 of the project.

In 2021 the team maintained the availability of the platform by establishing a process of exchanging faulty nodes with new or repaired ones. After years of successful operation, some of the nodes experienced disk or battery faults and required repairing. Because of COVID-19 restrictions and the suspension of the usual in-person events, this process was more challenging and was organised mainly by post with the cooperation of the involved NRENs.

The WP6 Task 3 team constantly monitors the usage, availability and performance of the central infrastructure and nodes through a dedicated Grafana-based monitoring solution. This allowed the team to spot a few issues related to the pScheduler implementation and report them to the perfSONAR development team. During 2021 the central instance of Grafana monitoring was migrated to the latest version (v8).

The Performance Measurement Platform was presented as a part of the WP6 work at the following events:

- Workshop on Network Management and Monitoring Tools, 24 March 2021 [Workshop_NMMT].
- 2nd European perfSONAR User Workshop, 14–15 April 2021 [perfSONAR_2UW].

The Platform was also included in Issue 38 of GÉANT's *CONNECT* magazine, in an article titled "perfSONAR, the ever evolving performance toolkit" [CONNECT_38].

2.5 WiFiMon

WiFiMon is a monitoring and performance verification system for WiFi networks. It is capable of detecting performance issues, visualising the achievable throughput of a wireless network for each user, and providing technical information about a WiFi network, e.g., signal strength, link quality, bit rate, etc. WiFiMon leverages well-known performance verification tools (e.g. Akamai Boomerang and Speedtest) and in addition uses data from the WiFi physical layer in order to gather a comprehensive set of WiFi network performance metrics. WiFiMon has been a production GÉANT service since 2 July 2020.

2.5.1 Users, Uptake and Usage

WiFiMon users can be NRENs, universities, research organisations, individual users, network providers with IEEE802.1x-enabled wireless networks, and/or commercial companies (such as ISPs).

WiFiMon can be used in two different ways:

1. Users download and install all WiFiMon components on-premise. This way, all the measurement data that can contain some personally identifiable information (e.g. IP addresses, MAC addresses) does not leave the user's infrastructure.
2. The most complex WiFiMon component, the WiFiMon Analysis Server (WAS), can also be provided on the NMaaS infrastructure, with the rest of the system still installed on-premise.

This mode is suitable for those users who want to quickly test WiFiMon capabilities before investing more time, effort and resources in a full on-premise installation.

WiFiMon can be adopted by NRENs for their own infrastructure, or potentially used where they offer Campus Network Management as a Service (CNaaS) services. It is more likely, though, that an NREN's organisations – universities, colleges or schools – will deploy it, as they directly manage the campuses where the monitoring can be beneficial. Another use case where WiFiMon can be very beneficial is where a wireless network consists of equipment from multiple different vendors, where the usual wireless monitoring solutions (such as those integrated with commercial wireless controllers) might not support all equipment types. WiFiMon measures network quality and performance regardless of the equipment vendor types or numbers. As such it can also be used at conference or meeting venues, or other ad hoc, temporary WiFi deployments where full control of the infrastructure might not be available.

Despite COVID-19, which had a very negative impact on WiFiMon usage due to most campuses being closed for long periods during 2020 and 2021, 8 organisations implemented WiFiMon as reported in Table 2.5 below.

Service Adoption 2021	
NREN use	During 2021 WiFiMon started to gain its first users from the community of European NRENs, but also from some abroad (e.g. RENU from Uganda).
Estimated number of users	The estimated current number of users is 8. It includes users from GRNET, RASH, GRENA, AMRES, RENU (Uganda), NORDUnet, HEAnet and EENet/Harno.

Table 2.5: WiFiMon service adoption for the period 01 January 2021 – 31 December 2021

2.5.2 Key Performance Indicators

The following KPIs are defined for WiFiMon:

- Number of software releases per year, with a target of at least 1 release per year.
- Number of dissemination activities / assisted organisations, with a target of at least 5 activities per year.
- Number of installations. The initial version of the WiFiMon software did not have the capability to measure this KPI. With the help of WP9, the measurement model for this KPI has been defined; this version-checking feature was added as a new software feature, and has been included since version 1.3.0 (published 1 April 2021).

KPI	Baseline 01/01/19 (start of GN4-3)	Target 31/12/22 (end of GN4-3)	Achieved Result (end of 2021)
Number of software releases per year	N/A	3	2
Number of dissemination activities/assisted organisations	N/A	15	16

KPI	Baseline 01/01/19 (start of GN4-3)	Target 31/12/22 (end of GN4-3)	Achieved Result (end of 2021)
Number of installations	N/A	5	8

Table 2.6: WiFiMon KPI targets and results for the period 01 January 2021 – 31 December 2021

2.5.3 Activities

WiFiMon became a production service on 2 July 2020. Service operation processes such as user support, request fulfilment, access management, application and technical management were established and fully operational. Throughout the reporting period, the team continued to work on service improvements and released two major versions (1.3 and 1.4). New features included the automation of installation procedures, adding new measurements (mainly data about the WiFi and neighbouring WiFi network parameters required by the eduroam team), code changes following the code review carried out by WP9, exporting WiFi monitoring data in the eduroam-defined JSON format, importing and analysing RADIUS logs for the measurement result correlation, and a version-checking feature that allows the number of active WiFiMon instances to be counted. The WiFiMon team supported RENU, RASH, GRENA and AMRES in the establishment of their new WiFi monitoring infrastructures.

The WiFiMon team also focused on service promotion. The team organised an infoshare [Infoshare_WiFiMon], which attracted 56 participants, and presented the service at several different events in the NREN community and the IEEE WONS conference. With the help of the WiFiMon team, WP3 prepared a short video about WiFiMon which is publicly available on YouTube [WiFiMon_Video] alongside the presentations from the previously mentioned conference and infoshare. Separate video conferences were held with several NRENs in Europe (e.g. CARNET, RENAM, CyNet), the eduroam team and some institutions such as University of Michigan and cnlab from Switzerland about potential cooperation and use of the service. A WiFiMon event was also organised for the EaP region in November 2021 [WiFiMon_EaP], from which interest from a number of NRENs grew.

3 Services at Earlier Lifecycle Stages

In addition to the production services covered in Section 2, GN4-3 WP6 is also working on a variety of other potential services that are at earlier stages in their lifecycle, namely:

- Argus, an alarm aggreggation and correlation tool.
- High-speed network monitoring.
- Streaming telemetry.
- P4-based flow monitoring.
- TimeMap, a per-segment latency and jitter measurement tool.
- In-band Network Telemetry (INT).

This section presents an overview of each of these. Work on the first four topics – Argus, high-speed network monitoring, streaming telemetry and flow monitoring – is conducted in WP6 Task 3, while TimeMap and INT are ongoing work in Task 1. The potential for a standalone service has been recognised for Argus and TimeMap and both are now being prepared to transition from development to production. The presented topics thus look into alternative methods for network management and monitoring, complementing – and/or with the potential to replace – currently implemented and used methods and tools.

3.1 Argus – Alarm Aggregation and Correlation Tool

Argus is a tool for network element and measurement system alarm correlation. It is tailored for the Campus Network Management as a Service (CNaaS) use case in which an NREN monitors and manages multiple campus networks. With Argus, an NREN can track all the alarms coming from multiple campuses and can also identify whether there are any correlated events. The Argus tool was developed by the Norwegian NREN Sikt (formerly Uninett) and at the time of writing this report it is used in production in Sikt and SUNET, while DeiC is in the process of evaluating the system for their internal use. The code is available on GitHub at [Argus_code1], [Argus_code2].

Argus was presented at the infoshare "Offering Campus Network Management as a Service: Challenges and Lessons Learnt" (October 2020) [Infoshare_OfferCNaaS], the Workshop on Network Monitoring and Management Tools (March 2021) [Workshop_NMMT], the GÉANT infoshare "Tools for Campus Network Management as a Service (CNaaS)" (April 2021) [Infoshare_ToolsCNaaS], the 14th SIG-NOC meeting (June 2021) [SIG-NOC_14] and the 25th STF meeting (February 2022) [STF_25].

Since there is a potential for Argus to become used by several NRENs, WP6 T3 initiated an Argus code review with the WP9 software audit team near the end of 2021. It is also working towards passing other PLM gates to push Argus to become a production service.

More information can be found on the WP6 open wiki at [Argus].

3.2 High-Speed Network Monitoring

In the period October 2021 – January 2022 the WP6 T3 team performed a set of experimental measurements over 100G links within the GÉANT network and between the GÉANT network and destinations in the RNP network (Brazil). The systems in the GÉANT network were kindly provided by the GÉANT team and SURF.

This set of measurements included a range of successful high-speed throughput tests using a range of different tools and end-station network setups. Rates of over 90 Gbps were achieved between SURF and sites in RNP, primarily using multi-stream iPerf. An interesting aspect of the tests was having access to quite fine-grained throughput and associated measurement parameters thanks to the streaming telemetry system provided by SURF.

At the time of writing this report, the results are being summarised and are scheduled to be reported at the 2nd Performance Management workshop in March 2022 and in a separate white paper.

Other threads of work being explored for high-speed network monitoring include performance analysis of RARE/FreeRtr and collaboration with WLCG sites on monitoring of 100G links with perfSONAR. The RARE/FreeRtr platform was used at the University of Amsterdam in the 2021 Data Mover Challenge, where one team achieved rates of over 80 Gbps to Singapore and Australia. The aim of the perfSONAR testing is to improve results in an initial MaDDash mesh such that results for single stream iPerf tests initially achieve 15 – 20 Gbps (noting that for full use of 100G an application would typically use multiple concurrent streams or flows).

3.3 Streaming Telemetry

The WP6 T3 network telemetry team worked on the standards-based network performance features recently added to the network elements of key vendors including Cisco and Juniper, and in particular on using new streaming telemetry techniques to stream monitoring results towards telemetry collectors. The work is summarised in a *Zero Footprint Monitoring* white paper [WP_Zero] published in December 2020, which is written in a cookbook style in order to help NRENs to use these technologies. The results of this work were directly used by the T1 low latency networking team for the TimeMap tool, with implementation support provided by the T3 team.

The results were also presented and discussed at the first Telemetry and Big Data Workshop in November 2020, which was attended by 134 participants [TBDW].

3.4 P4-Based Flow Monitoring

After completing the work on streaming telemetry, the same team within WP6 T3 started to explore the use of P4-enabled network cards in servers for unsampled network flow (e.g. IPFIX, Netflow) gathered at high-speed links (10 Gbps and above). Previous work in SWITCH [P4_SWITCH] and at some universities [P4_UoP] showed that programmable cards can offload some of the packet processing work and achieve higher unsampled flow rates than the off-the shelf network elements. The cards used in this work are those with the Netronome NFP-4000 flow processor. At the time of writing this report the work is still in progress, with the first prototype being ready for testing.

3.5 TimeMap – Per-Segment Latency and Jitter Measurement Tool

The first of the two network monitoring tools being worked on in Task 1 is TimeMap, which collects latency measurements made between routers on the GÉANT network backbone and presents a GUI through which per-segment latency and jitter measurements can be visualised.

Measurements have been made using both Juniper real-time performance monitoring (RPM) and standard Two-Way Active Measurement Protocol (TWAMP), with results collected through Telegraf and presented using Grafana. The tool is being adopted by the GÉANT Operations team.

The results from Task 1's work, including TimeMap, are summarised in Deliverable D6.7 *Network Technology Evolution Update* [D6.7].

More information on TimeMap, including the team's contact details, can be found on the WP6 open wiki at [TimeMap].

3.6 In-band Network Telemetry (INT) on Programmable Network Hardware

The work on In-band Network Telemetry in Task 1 stemmed from an exploration of the potential use cases for data plane programmability in R&E networks.

The team has deployed a testbed across three NREN networks, and sent packets with INT data over the networks where they are collected by an INT sink node, and exported to a database from which the results are visualised.

The results from Task 1's work, including INT, are summarised in Deliverable D6.7 *Network Technology Evolution Update* [D6.7].

More information can be found on the WP6 open wiki at [INT].

4 Conclusions

This document has presented an overview of the current status of the five production services managed by WP6 Task 3 – perfSONAR, perfSONAR Consultancy and Expertise, Network Management as a Service (NMaaS), the Performance Measurement Platform (PMP) and WiFiMon – and of six other earlier-lifecycle activities in Task 1 and Task 3 that may lead either to new service development (Argus and TimeMap being the most advanced) or to knowledge transfer towards the NRENs (high-speed network monitoring, streaming telemetry, P4-based flow monitoring, and INT on programmable network hardware).

For the production services, this document has summarised the status of the services after three years of the GN4-3 project, user adoption, KPIs and the ongoing activities on service operations and improvement. It can therefore be used as a report of the production service status for WP6 Task 3 and for comparison with the status of the services at the beginning of the project, summarised in the Deliverable D6.1 *Network Management and Monitoring Portfolio* [D6.1]. For other, earlier-lifecycle activities, the document has given the current status of their development.

Current network monitoring work in WP6 shows clearly the central role of perfSONAR in multiple GÉANT services (perfSONAR, perfSONAR Consultancy and Expertise and PMP) and developments: high-speed network monitoring uses perfSONAR monitoring tools, WiFiMon is testing the use of TWAMP for its hardware probe measurements, and TimeMap benefited from perfSONAR-based measurement and analysis in the design process. Its modular, extensible architecture and the ability to include additional monitoring tools make it potentially suitable for many of the types of measurements that are now under development. Further, the new features that will be a part of the perfSONAR suite from version 5.0, and its use of the well-known Elasticsearch, Logstash and Kibana (ELK) platform as a backend, have the advantage of being compatible with the typical current developments and toolsets NRENs often use. Therefore, WP6's strategic plan is to maintain the project presence in the global perfSONAR development consortium, and to explore its use for the new technology and network and service monitoring methods that emerge.

The WP6 work on network management mechanisms has shown a low level of interest among the NRENs in developing a single methodology, management-supporting system architecture and set of Operations Support Systems (OSSs) that could be used by multiple NRENs. The implication of this is that any broader OSS development would not be likely to be reusable by a large number of NRENs. On the other hand, many NRENs are facing an increased demand to work on infrastructure management activities of their end institutions, through Campus Network Management as a Service (CNaaS). NMaaS is a microservice-based platform which does not mandate the use of a specific infrastructure monitoring methodology or OSS toolset. It allows the installation of various management support applications in a secure and multi-tenant fashion where each end institution

can have its own instance. Such an approach, and the increased NMaaS service uptake, show that the further development and investment in the service is justified.

All the production services have met or exceeded their KPI targets. Overall, the portfolio of network management and monitoring services continues to fulfil GÉANT's objective of ensuring that the services it offers are current, effective, address real NREN demands and are well used.

References

[Argus]	https://wiki.geant.org/display/NETDEV/Argus
[Argus_code1]	https://github.com/Uninett/Argus
[Argus_code2]	https://github.com/Uninett/Argus-frontend
[CONNECT_38]	https://connect.geant.org/tag/connect38
[D6.1]	Deliverable D6.1 *Network Management and Monitoring Portfolio*
	https://geantprojects.sharepoint.com/:b:/r/sites/gn4-3/Work-Packages/WP6/Deliverables%20Documents/Network%20Management%20and%20Monitoring%20Portfolio/D6-1_Network-Management-and-Monitoring-Portfolio.pdf?csf=1&web=1 [login required]
[D6.7]	Deliverable D6.7 *Network Technology Evolution Update*
	https://geant.org/wp-content/uploads/2022/01/D6.7-Network_Technology_Evolution_Update.pdf
[GARR_Workshop]	https://www.eventi.garr.it/en/ws21/home
[GNSym_2020]	https://geantprojects.sharepoint.com/sites/gn4-3/Work-Packages/WP2/T3/Pages/GN4-Symposium-2020.aspx [login required]
[Infoshare_NMaaS]	https://www.youtube.com/watch?v=LUN_HBpbSlk&feature=youtu.be
[Infoshare_OfferCNaaS]	https://events.geant.org/event/68/
[Infoshare_ToolsCNaaS]	https://events.geant.org/event/690/
[Infoshare_WiFiMon]	https://events.geant.org/event/221/
[INT]	https://wiki.geant.org/display/NETDEV/INT
[Jisc_Networkshop49]	https://www.jisc.ac.uk/events/networkshop49-27-apr-2021
[NMaaS]	https://nmaas.eu
[NMaaS_GNSym2020]	https://wiki.geant.org/download/attachments/138741721/Symposium%20Demo%20v1.pptx?api=v2 [login required]
[NMaaS_IG]	https://wiki.geant.org/display/NMAAS/NMaaS+Installation+Guide
[NMaaS_Sandbox]	https://nmaas.geant.org
[NMaaS_STF18]	https://wiki.geant.org/download/attachments/126977976/STF%20NMaaS%20v1.0.pdf?api=v2 [login required]
[NMaaS_STF21]	https://wiki.geant.org/download/attachments/148091542/GN4-3-WP6-T3-STF21-NMAAS-20201026.pptx?api=v2 [login required]
[NMaaS_WorkshopNMM]	https://wiki.geant.org/download/attachments/131629403/WoNM%26M%20Copenhagen%20October%202019%20NMaaS%20as%20a%20platform%20for%20management%20service%20outsourcing%20v1.0.pdf?version=1&modificationDate=1571729689774&api=v2 [login required]
[OpenVPN]	https://openvpn.net/
[P4_SWITCH]	https://wiki.geant.org/download/attachments/148094173/A-Gall_netflow.pdf?version=2&modificationDate=1604927806000&api=v2

[P4_UoP]	https://cdn.open-nfp.org/media/documents/WBN-2017-11-1-Penn-Feature-Rich-Flow-Monitoring-OpenNFP.pdf
[perfSONAR_2UW]	https://wiki.geant.org/display/perfSONAR/2nd+European+perfSONAR+User+Workshop
[perfSONAR_Docs]	https://docs.perfsonar.net/
[perfSONAR_GitHub]	https://github.com/perfsonar/
[perfSONAR_Usage]	https://stats.es.net/ServicesDirectory/
[perfSONAR_Webmail]	https://lists.internet2.edu/sympa/info/perfsonar-user
[perfSONAR_Website]	https://www.perfsonar.net/
[perfSONAR_Wiki]	https://wiki.geant.org/display/gn43wp6/perfSONAR+International+Project
[perfSONARC&E_Wiki]	https://wiki.geant.org/display/gn43wp6/perfSONAR+Consultancy+and+Expertise
[PMP_DA]	L. Hrboka, "PMP Data Analysis", TechEXtra 2021: perfSONAR Day, 3.11.2021
[STF_18]	https://wiki.geant.org/display/APM/18th+STF+-+Copenhagen%2C+Oct+2019 [login required]
[STF_21]	https://wiki.geant.org/pages/viewpage.action?spaceKey=APM&title=21st+STF+-+%28Virtual%29%2C+October+2020 [login required]
[STF_23]	https://wiki.geant.org/display/APM/23rd+STF+-+by+VC%2C+July+2021 [login required]
[STF_24]	https://wiki.geant.org/display/APM/24th+STF+-+by+VC%2C+October+2021 [login required]
[STF_25]	https://wiki.geant.org/pages/viewpage.action?spaceKey=APM&title=25th+STF+by+VC%2C+February+2022 [login required]
[SIG-NOC_14]	https://wiki.geant.org/display/SIGNOC/14th+SIG-NOC+meeting+-+virtual
[TBDW]	https://wiki.geant.org/display/PUB/Telemetry+and+Big+Data+Workshop
[TimeMap]	https://wiki.geant.org/display/NETDEV/Timemap
[TNC21]	https://tnc21.geant.org/
[UKNOF_48]	https://indico.uknof.org.uk/event/55/
[UptimeRobot]	https://uptimerobot.com/
[WiFiMon_EaP]	https://events.geant.org/event/1070/
[WiFiMon_Video]	https://www.youtube.com/watch?v=9LuGlF6JSnA
[Wiki2]	https://wiki.geant.org/display/gn43wp6/perfSONAR+Consultancy+and+Expertise
[WireGuard]	https://www.wireguard.com/
[Workshop_NMM]	https://wiki.geant.org/display/PUB/Workshop+on+Network+Management+and+Monitoring
[Workshop_NMMT]	https://events.geant.org/event/387/
[WP_Zero]	https://about.geant.org/wp-content/uploads/2021/12/Zero-Footprint-Monitoring.pdf

Glossary

API	Application Programming Interface
BELLA	Building the Europe Link to Latin America
CNaaS	Campus Network Management as a Service
DNS	Domain Name Service
ELK	Elasticsearch, Logstash and Kibana
FreeRtr	freeRouter
GUI	Graphical User Interface
HTTP	Hypertext Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
INT	In-band Network Telemetry
IP	Internet Protocol
IPR	Intellectual Property Rights
ISP	Internet Service Provider
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LHC	Large Hadron Collider
MAC	Media Access Control
MaDDash	Monitoring and Debugging Dashboard
MP	Measurement Point
NMaaS	Network Management as a Service
NMS	Network Management System
NOC	Network Operations Centre
NREN	National Research and Education Network
OSS	Operations Support System
perfSONAR	Performance-focused Service Oriented Network monitoring Architecture
PERT	Performance Enhancement Response Team
PLM	Product Lifecycle Management
PMP	Performance Measurement Platform
R&E	Research and Education
RADIUS	Remote Authentication Dial-In User Service
RARE	Router for Academia, Research and Education
RNP	Rede Nacional de Ensino e Pesquisa, the Brazilian NREN
RPM	Real-time Performance Monitoring
STF	Service and Technology Forum
T	Task
TEIN	Trans-Eurasia Information Network
TNC	The Networking Conference

TWAMP	Two-Way Active Measurement Protocol
UI	User Interface
VPN	Virtual Private Network
WAS	WiFiMon Analysis Server
WLCG	Worldwide LHC Computing Grid
WONS	Wireless On-demand Network systems and Services Conference
WP	Work Package
WP6	Work Package 6 Network Technologies and Services Development
WP9	Operations Support
WP6 T1	WP6, Task 1 Network Technology Evolution
WP6 T3	WP6, Task 3 Monitoring and Management