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Deliverable D6.3 Network Monitoring Solutions

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Authors:	Lætitia Delvaux (PSNC), Szymon Trocha (PSNC), Elisantila Gaci (RASH), Vidar Faltinsen (SIKT), Claudio Allocchio (GARR), Ivana Golub (PSNC), Pavle Vuletić (UoB/AMRES), Ljubomir Hrboka (CARNET)

Abstract

This deliverable provides an update of several network monitoring services in production as well as other ongoing activities undertaken as part of GN5-1 Monitoring Task (Task 3) of the Network Development work package (WP6).

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Executive Summary

The Monitoring Task (Task 3) of the Network Development work package (WP6) in the GÉANT Network 5 Phase 1 (GN5-1) project is responsible for several production network monitoring services, i.e., Argus, perfSONAR, the Performance Measurement Platform (PMP), TimeMap and WiFiMon. Additionally, WP6 T3 is also exploring the analysis of the PMP measurement data and applying the TimeMap architecture to the monitoring of the GÉANT Core Time and Frequency Network that is now being deployed. All the above services are aimed at the GÉANT community at large.

This document presents the network monitoring service portfolio after 1.5 years of the project, together with ongoing work and new initiatives in Period 2 of GN5-1 by WP6 Task 3. 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 GN5-1 project's Network Development work package (WP6), the Monitoring Task (Task 3) works on further developing and evolving network monitoring and management tools and services for the GÉANT community.

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

- Argus – An open-source, alarm aggregation and correlation tool that enables Network Operations Centres (NOCs) and service desks to aggregate incidents from multiple monitoring applications into a single, unified dashboard and notification system.
- perfSONAR – Consists of two sub-activities:
  - The development and user support of the perfSONAR software for active performance monitoring within the international collaboration with ESnet, Internet2, Indiana University, RNP and the University of Michigan.
  - The consultancy and expertise service provided to the GÉANT community.
- Performance Measurement Platform (PMP) – Provides an open, trusted, monitoring and measurement information infrastructure. This is currently based on perfSONAR but is open to adopting additional tools.
- TimeMap – A tool that collects and visualises latency and jitter measurements over the GÉANT backbone network, helping to verify network anomalies and performance issues.
- WiFiMon – A hybrid, crowd-sourced and/or hardware probe-based Wi-Fi 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 Wi-Fi network.

In parallel with this operation and development work, Task 3 is also leveraging the TimeMap architecture to monitor key metrics of Optical Time and Frequency Networks (OTFN) and continuing to analyse a large amount of historical measurement data gathered from the PMP measurement points, correlating this data with specific network events. This exploration led to the publication of a white paper, "PMP Data Analysis" [PMP-Data]. Task 3 has also written two other white papers, together with Task 4, applying the TM Forum's Open Digital Architecture terminology to describe the Argus [ODA-Argus] and PMP services [ODA-PMP].

This document presents a snapshot of the status of the Task 3 network management and monitoring services after 1.5 years of the GN5-1 project. Section 2 describes the current status of the services in production, covering users, uptake and usage, key performance indicators, and activities; with conclusions outlined in Section 3.

2 Services in Production

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

- Argus
- perfSONAR
- Performance Measurement Platform (PMP)
- TimeMap
- WiFiMon

For each service it provides a high-level description, information on users, uptake, usage, values of key performance indicators (KPIs), and a description of recent and ongoing activities.

2.1 Argus

Argus [ARGUS] is an open-source tool for Network Operations Centres (NOCs) and service desks to aggregate incidents from all their monitoring applications into a single, unified dashboard and notification system. Most NOCs will, out of necessity, use a myriad of applications to monitor their infrastructure and services. In turn, they need to contend with manually managing notification profiles and monitoring dashboards in each individual application. Argus mitigates these scenarios by providing the NOC with a singular overview of actionable incidents, and by providing a single point of notification configuration and visualisation. Argus does not provide a monitoring service itself; it is lightweight by design, focusing on one thing: managing the alarms of underpinning monitoring applications.

Argus is agnostic of the details of each monitoring application but instead provides a REST API to report new incidents, and to search, fetch or update the status of previously registered incidents. Glue services, software pieces giving access to other applications' alarms or data, already exist for several source applications, and more can be easily written using the documented API and/or existing API client libraries for Python. Incidents are associated with a source application and can be tagged with arbitrary metadata from the source application, including URLs to drill down into incident details in the source application. Metadata can be used to make arbitrary incident filters, which can be applied both in the dashboard UI and in notification profiles. Mechanisms also exist to add acknowledgements to incidents and to link incidents with tickets in the NOC's ticketing application. The data model even supports registering inter-relationships between incidents. Notifications via e-mail and SMS are supported, while more mediums are planned.

Argus provides federated login. Users can sort and filter the alarms in their personal view and can set up flexible, personal alarm notification profiles. Argus has proven useful in providing a distinct interface between individual product teams and an organisation's NOC when it comes to defining which monitoring alerts should be handled by the NOC, and which ones the product teams will handle themselves.

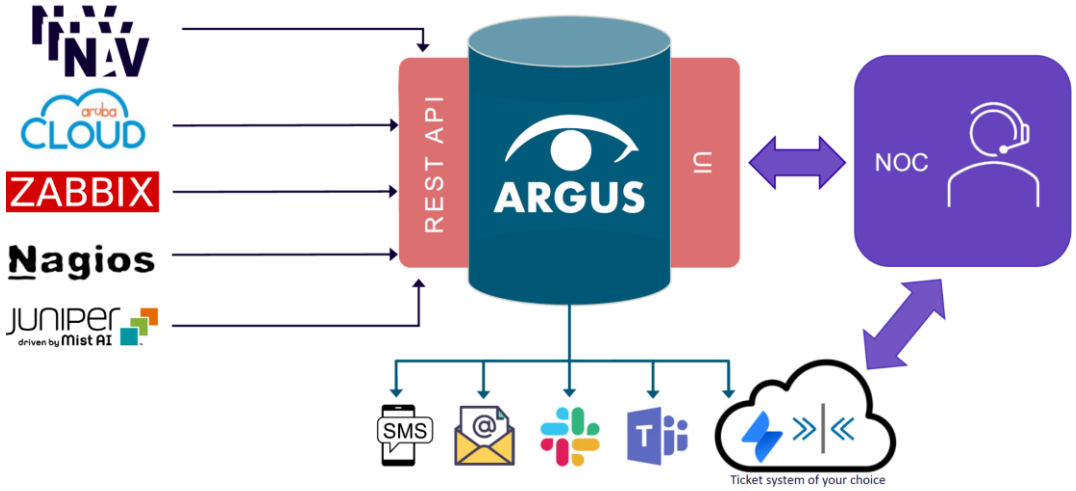

Figure 2.1: The Argus architecture

Argus is open source, mainly developed by resources from Sikt (Norwegian NREN) and supported by GN5-1. Launched in November 2022, it is available on GitHub for installation free of charge.

2.1.1 Users, Uptake and Usage

Argus's target users are personnel at an NREN's/organisation's NOC or service desk. Argus is also an important tool for L2 and L3 system/network engineers, who can use it to set up their personal alarm profiles. Since the user group is quite narrow, the number of users will be moderate. Sikt has a total of 60 users.

Argus is in production at three NRENs; Sikt, SUNET (Swedish NREN) and REANNZ (New Zealand NREN). In addition, the University of Helsinki has a running installation and the University of Agder has a trial. Sikt has implemented glue services for NAV [NAV], Aruba (Wi-Fi) [ARUBA] and Juniper MIST (Wi-Fi) [MIST]. SUNET has implemented a glue service for Nagios [NAGIOS] and REANNZ has implemented a glue service for Prometheus [PROMETHEUS].

GÉANT is committed to replacing the current dashboard at their NOC with Argus by the end of 2024. Sikt and GÉANT are collaborating on reimplementing the Argus front-end to make it more flexible and thus feasible to support the GÉANT NOC workflow and requirements.

All together 28 NRENs have so far shown interest in Argus. Four of these stated in the GÉANT Satisfaction Survey (spring 2024) that it is very likely they will install Argus, and nine state it is likely.

2.1.2 Key Performance Indicators

The key performance indicators for Argus are shown in Table 2.1.

KPI	Baseline (start of GN5-1)	Target (end of GN5-1)	Measured (end of June 2024)
Number of feature releases per year	N/A	2	16 (9 for the back end, 7 for the front-end)

KPI	Baseline (start of GN5-1)	Target (end of GN5-1)	Measured (end of June 2024)
Number of new installations per year	2	4	4
Number of dissemination events per year	N/A	8	6

Table 2.1: Argus KPI targets and results for the period 1 January 2023 to 30 June 2024

Comments on these KPIs are found in the next section.

2.1.3 Activities

There have been 16 feature releases so far in GN5-1: seven for the front-end and nine for the back end. The main improvements include:

- Two-way-ticket system integration (supporting Request Tracker [RT], Jira [JIRA], GitHub [GITHUB] and GitLab [GITLAB]). This allows for a more efficient workflow at the NOC as tickets can be created directly from Argus.
- Bulk update support in the alarm management view. This is a very helpful feature when the NOC receives large numbers of alarms that should be dealt with in the same manner.
- Improved alarm profile functionality, including support for more alarm channels. Email, SMS and MS Teams are now fully supported, allowing for flexibility in choice for Argus users.
- In addition, the team is implementing support for Helm charts (packet manager for Kubernetes [KUBERNETES]) to ease the installation process.

There have been two new installations in the reporting period: REANNZ and the University of Helsinki.

Six dissemination events have taken place:

- Presentation at the 18th SIG-NOC meeting, May 2023, Stockholm, Sweden [SIG-NOC-18].
- Lightning talk at TNC23, June 2023, Tirana, Albania [TNC23].
- Lightning talk at the GÉANT GN5-1 Symposium, December 2023, Montpelier, France.
- Presentation for RENU, February 2024, Uganda.
- Combined Zino and Argus talk at SIG-NOC, May 2024, Helsinki, Finland [ZINO] [SIG-NOC-20].
- Presentation in the CNaaS BoF at TNC24, June 2024, Rennes, France [TNC24].

General feedback from the community is that Argus has a unique approach and can be proven useful for many NRENs and universities, however, it is still too cumbersome to install and there should be more glue services available. It will be a priority for the Argus development team to address these two issues.

2.2 perfSONAR

perfSONAR is an open-source, modular and flexible architecture for active network performance monitoring. Installations worldwide provide a view of network performance across multiple domains, allowing Network Operations Centre (NOC) and Performance Enhancement Response Team (PERT) engineers to seamlessly analyse and diagnose network behaviours across an entire end-to-end path.

The tools provided in the perfSONAR suite perform active IPv4 and IPv6 measurements of throughput, packet loss, delays, jitter, HTTP and DNS response times, and record network route and path changes. Measurement

Points (MPs) installed independently on selected network paths can be coordinated and used together within a single organisation or between multiple partners. A lookup service lists all publicly available MPs, thus making the MPs – their status and measurements – visible outside of their own domain. This gives stakeholders from external domains the opportunity to perform measurements, subject to permissions being allowed, thus creating a multi-domain monitoring environment. The perfSONAR suite contains all necessary tools for setting up a successful performance monitoring architecture, including "meshes" of tests between nodes in a single community of interest and visualisation of the results as a red-amber-green dashboard or measurement graphs.

In GN5-1, the perfSONAR service is divided into two sub-activities:

- GÉANT participation in the **perfSONAR International Project**, an international collaboration with ESnet, Internet2, Indiana University, RNP and the University of Michigan.
- providing **perfSONAR Consultancy and Expertise** to the GÉANT community.

perfSONAR International Project

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

A number of information sources and support options are available for perfSONAR:

- Main website [perfSONAR_Website].
- Installation and usage documentation [perfSONAR_Docs].
- Developers' resources are available on GitHub [perfSONAR_GitHub].
- GN5-1 project contributions and related work is described in the [perfSONAR_Wiki].
- Support requests can be submitted through the global user mailing list perfsonar-user@internet2.edu.

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, use 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 email at perfsonar@lists.geant.org.

2.2.1 Users, Uptake and Usage

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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 2.2 shows a global subset of perfSONAR nodes registered in the central lookup service [perfSONAR_Stats]. As of June 2024, in addition to around 2,500 public nodes running more than 10,000 services, there are also several private installations implemented worldwide. The number of services depends on the version of perfSONAR and on which services the users have activated.

Figure 2.2 perfSONAR installations worldwide as of June 2024 taken from the Lookup Service Dashboard [perfSONAR_Stats]

There are about 500 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.

perfSONAR Consultancy and Expertise

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 (KPI) for perfSONAR measures the number of major perfSONAR releases per year. The key performance indicators for perfSONAR are shown below in Table 2.2.

KPI	Baseline	Target	Measured
Number of major perfSONAR releases in 2023 and 2024	2	2	2

Table 2.2: perfSONAR KPI measured for the period 1 January 2023 to 30 June 2024

The last major perfSONAR release, 5.1, was issued in June 2024. Version 5.0 was released in April 2023, with subsequent bug fix releases 5.0.1 to 5.0.8, from April 2023 to February 2024.

The key performance indicator for perfSONAR Consultancy and Expertise is the number of requests for consultancy that the team fulfils during the reporting period, as shown in Table 2.3.

KPI	Baseline	Target	Measured
Number of requests for consultancy fulfilled	3	3	4

Table 2.3: perfSONAR Consultancy and Expertise KPI measured for the period 1 January 2023 to 30 June 2024

2.2.3 Activities

perfSONAR International Project

The work of the global perfSONAR team is currently focused on providing support for the newly released Version 5.1 and preparing the next major releases of perfSONAR (Versions 5.2 and 5.3), which will bring new visualisations and ways to look at measurement data. The GÉANT project team contributed to building, testing and fixing all Debian/Ubuntu packages, improving the user interface (UI), providing a new graphical UI (psGUI) for pScheduler, and testing and debugging perfSONAR 5.1 and other latest releases. The team is responsible for providing the Debian build, distribution and testing infrastructure, in line with the latest Debian and Ubuntu standards.

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

Another development activity performed by the GÉANT team is the design and implementation of the Lookup Service dashboards [perfSONAR_Stats] that list and document all perfSONAR public installations, worldwide. This service is provided thanks to a Grafana instance running on the NMaaS [NMAAS] infrastructure. It is regularly updated to the latest Grafana [GRAFANA] version to stay current and improve the user experience.

The GÉANT team also co-chairs training and documentation activities. Within the perfSONAR International 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 [perfSONAR_Youtube].

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

- 11th SIG-NGN, April 2023, Prague, Czech Republic [SIG-NGN-11].
- 18th SIG-NOC, May 2023, Stockholm, Sweden [SIG-NOC-18].
- Internet2 TechEX conference, Sep 2023, Minneapolis, MN, USA [TechEX23].
- Network Performance and Monitoring Workshop, February 2024, remote [NPMW].
- 4th European perfSONAR User Workshop, May 2024, Trondheim, Norway [pS-Workshop].

perfSONAR 5.0 was the subject of a GÉANT InfoShare in March 2023, just before the 5.0 release.

perfSONAR Consultancy and Expertise

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

- RENATER to renew their perfSONAR internal deployment.
- CYNET for an initial deployment alongside the PMP node already running.
- FCCN to deploy perfSONAR instances running in containers in their whole network.
- GridPP (WLCG UK) and general WLCG network to run 100 Gbps measurements on their network.

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

- 11th SIG-NGN, April 2023, Prague, Czech Republic [SIG-NGN-11].
- 18th SIG-NOC, May 2023, Stockholm, Sweden [SIG-NOC-18].
- Internet2 TechEX conference, September 2023, Minneapolis, MN, USA [TechEX23].

The perfSONAR GÉANT team also organised the 4th perfSONAR User Workshop, a three-day event that brought together 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 from 14 to 16 May 2024, in Sikt premises, Trondheim, Norway [perfSONAR_Workshop].

2.3 Performance Measurement Platform (PMP)

The Performance Measurement Platform (PMP) is 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.

The Performance Measurement Platform includes 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.

The PMP 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, as well as to several MPs worldwide that correspond to intercontinental GÉANT network connectivity, e.g. via BELLA to South America and TEIN to Asia. Several regular tests are performed: throughput, latency, traceroute, HTTP request time and DNS query time to measure application-specific parameters.

The central components that manage the platform elements and gather, store and represent the performance data are operated and maintained by the WP6 Task 3 team. The team has also implemented automation using Ansible [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.

2.3.1 Users, Uptake and Usage

PMP has two 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 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.

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 GN5-1 project. Some of the nodes are used for research and development as well as for testing purposes by the PMP service team. As a new type of deployment, some organisations have also established a PMP node as a virtual machine (VM) or in a container. All nodes are managed by the PMP team in WP6 Task 3 in collaboration with the hosting organisation.

2.3.2 Key Performance Indicators

The KPIs used to measure the success of the PMP infrastructure are shown below in Table 2.4.

KPI	Baseline	Target	Measured
Availability of the central infrastructure	N/A	100%	100%
The number of GÉANT project partner countries	48%	80%	89%
Overall user satisfaction	N/A	85%	85%

Table 2.4: PMP KPIs measured for the period 1 January 2023 to 30 June 2024

The availability of the central infrastructure is measured based on the availability of the MaDDash (graphical user interface) and measurement archives. The measured availability between 1 January 2023 and 30 June 2024 was 100%, while the target availability was 99%.

At the time of writing, a total of 50 nodes have been distributed amongst the PMP service participants, 34 of which went directly to GN5-1 project partners (NRENs). Other nodes are hosted amongst other interested organisations or used as testing instances by the PMP service team. The KPI focuses on the geographical service coverage and counts just the number of countries seen as GN5-1 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 undertaken during Period 1 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 was issued in 2023. Most users rated the PMP service as "Very Good" or "Good", with overall user satisfaction at 85%. Two ratings were "Moderate" from users seeking extensions toward TWAMP measurements and alarming features. The PMP team discusses these options together with the relevant software developers.

2.3.3 Activities

In 2023 the team started to migrate the nodes to the latest perfSONAR 5.0 version. This process will continue for all the remaining nodes over the coming months. This involved upgrading the PMP nodes to a new operating system, where possible, because most of the nodes were running CentOS7, which reached end-of-life in June 2024. Due to the change in the perfSONAR operating system support, the most popular choice for users is now Ubuntu 20/22. New operating system installation required local hands-on, therefore parts of the activities (upgrade of the operating system, installation of new version 5.0 of perfSONAR and configuring remote access) were done by the organisation hosting the probe. During this process, the PMP operation team supervised the upgrade and provided support to the hosting organisation. As the final step, the WP6 PMP team configured the nodes to complete remote access configuration, and system settings and join the PMP measurement mesh.

After years of successful operation, some of the nodes experienced disk or battery faults and could no longer be repaired. In GN5-1 the team maintained the availability of the PMP service by establishing a process of exchanging faulty nodes that could not be repaired to a solution based on virtual machines provided by the hosting NRENs. When provided, the VMs were configured in the same way as other hardware-based nodes by the PMP operation team.

In 2023, the perfSONAR project released a new central Measurement Archive that replaced the old Esmond database [ESMOND] with a more robust OpenSearch [OPENSEARCH]. It also delivered a replacement for MaDDash through a Grafana-based interface (see Figure 2.3). These two new upgrades now allow new types of visualisation and are opening ways for the integration of different data sources in existing environments. The PMP operation team deployed a new central Measurement Archive with these new features. Until the migration of all PMP nodes has finished, the measurement mesh has been reconfigured to store test results in both archives: Esmond and OpenSearch. The team already configured the new Grafana dashboards using new types of visualisation for better data presentation.

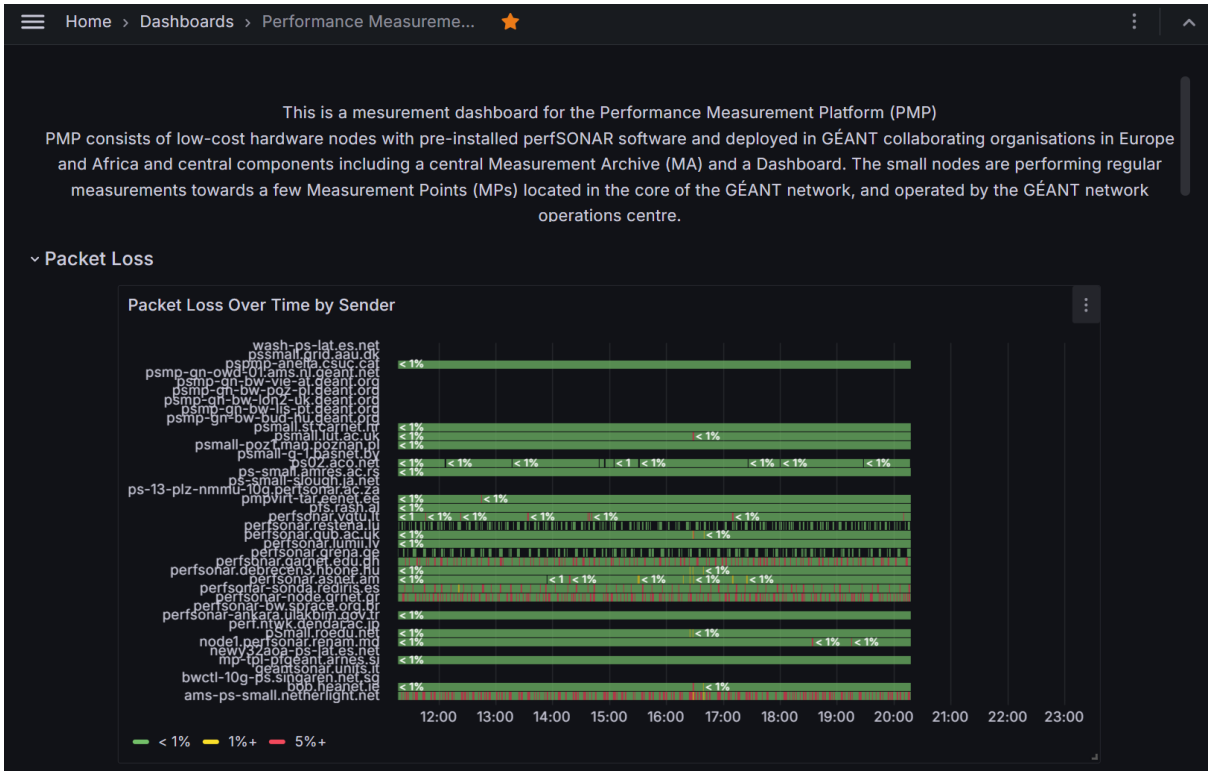

Figure 2.3: New PMP service measurement dashboard using Grafana interface

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 and OpenSearch measurement databases have a web API that enables these monitoring results to be accessed. PMP data analysis leverages this data to find innovative ways to use machine learning techniques to detect anomalies and deteriorating conditions on links within the GÉANT network. The ultimate goal is to obtain a holistic view of network performance and develop solutions that lead to faster and more accurate anomaly detection, improved decision-making, increased accuracy, and cost reduction. Work on developing an anomaly detection model using latency data is still ongoing. This is done using Autoencoder machine learning networks and Long Short-Term Memory networks. The first results have been obtained and presented in the white paper “PMP Data Analysis” and at the 4th European perfSONAR User Workshop [PMPDA-pSWS].

The WP6 Task 3 team constantly monitors the usage, availability and performance of the central infrastructure and nodes through a dedicated Prometheus and Grafana monitoring solution using the NMaaS infrastructure [NMAAS]. During 2023, a new type of dashboard was added to better visualise the pScheduler usage and load.

The Performance Measurement Platform was also a subject of detailed OAV architecture analysis, together with WP6 T4. It analysed the mapping of the PMP service architecture to the TM Forum’s Open Digital Architecture

to provide a standardised view of the orchestration, automation and virtualisation components and implementations within the service. The results were summarised and published in the white paper "PMP OAV Architecture Analysis" [PMP-OAV].

2.4 TimeMap

TimeMap is an open-source monitoring system dedicated to supporting real-time networked applications that need low latency and low jitter network transport. It collects per-segment latency and jitter measurements on a network backbone using two-way active measurement protocol (TWAMP) probes and provides an interactive visualisation of the measurement data through the TimeMap dashboard. The system is implemented using Telegraf [TELEGRAF], InfluxDB [INFLUXDB], and Grafana.

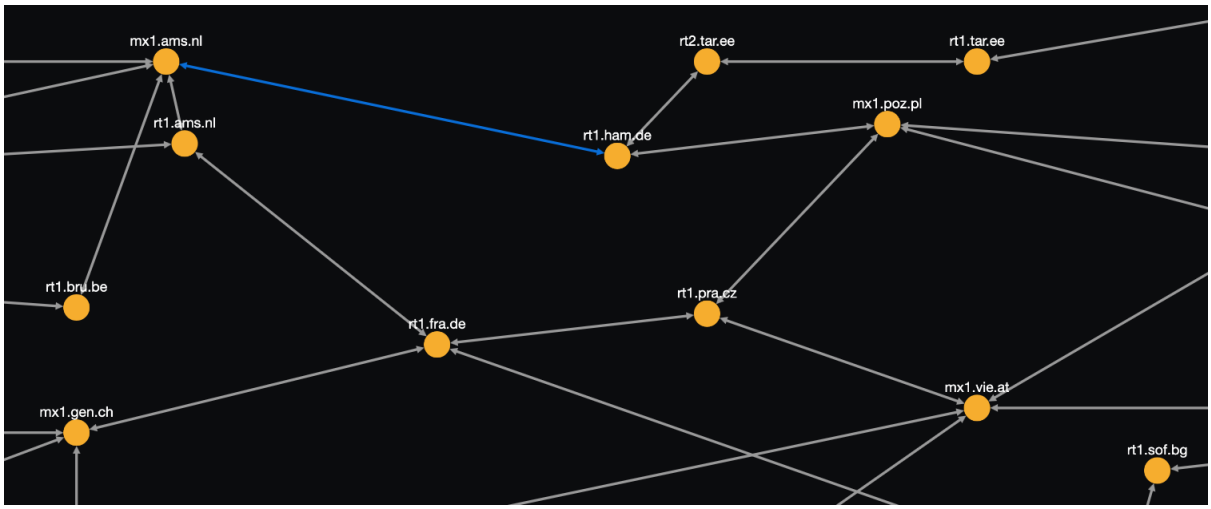

Figure 2.4: TimeMap latency-jitter weather map for GÉANT backbone

TimeMap is designed to help debug issues for real-time services such as (but not limited to) the LoLa audio-visual streaming application used by performing arts communities [LoLa], as it can identify activities on the backbone that affect latency and jitter parameters. Any other real-time service over the network can benefit from TimeMap monitoring.

TimeMap was created with two specific objectives: to use measurement tools included in the existing equipment to remove the need to deploy extra hardware (i.e., a zero-footprint monitoring solution), and to make the service as easily deployable inside an NREN's backbone as possible. To achieve these objectives, TimeMap is based on micro-services that can readily be adapted for deployment in the network of any NREN interested in having access to detailed latency and jitter measurements and visualisations.

TimeMap is a relatively new addition to the GÉANT Service Catalogue (it was launched in October 2022) and is available online [TimeMap], where it is accessible via eduGAIN federated login. The documented code has been published, together with a user guide and an admin guide on the GÉANT GitLab [TimeMap GitLab].

2.4.1 Users, Uptake and Usage

From 1 January 2023 to 30 June 2024, two TimeMap installations were performed: one on the Portuguese NREN FCCN and one of the Catalonia Regional Network. Both installations are in prototype state and receiving assistance from the TimeMap support team.

2.4.2 Key Performance Indicators

The key performance indicators for TimeMap are shown below in Table 2.5.

KPI	Baseline (start of GN5-1)	Target (end of GN5-1)	Measured (end of June 2024)
Number of feature releases per year	N/A	2	1
Number of new installations or assistance requests per year	1	4	2
Number of dissemination events per year	0	8	6

Table 2.5: TimeMap KPI targets and results for the period 1 January 2023 to 30 June 2024

2.4.3 Activities

TimeMap is now fully based on standard TWAMP protocol only and has been redeployed on the new GÉANT backbone. A more flexible user interface is being prepared, based on new features that became available in Grafana.

TimeMap also features an automated anomaly detection system: having historical data available, machine learning techniques are being applied to teach the anomaly module what deviates from "usual" patterns and as such, to pinpoint non-standard events. This module is under constant development at the moment, but it has already been quite effective. The module can also send automated alarms and in case trigger actions.

Dissemination activities included presentations at:

- The RIPE-SEE 11 conference, April 2023, Split, Croatia [RIPE-SEE 11].
- The RIPE #86, May 2023, Amsterdam, Netherlands [RIPE86].
- The NPAP Workshop, September 2023, Memphis, USA [NPAPW].
- The GÉANT Symposium, December 2023, Montpellier, France.
- The Network Performance and Monitoring Workshop, February 2024, remote [NPMW].
- The 20th SIG-NOC May 2024, Helsinki, Finland [SIG-NOC-20].

In GN5-1 TimeMap architecture is now also considered as a starting point for a monitoring tool for Optical Time and Frequency Network (OTFN) and services. Instead of focusing on checking latency and jitter, this new monitoring solution will look at parameters relevant to time and frequency network and services, but follow the same architectural principle as TimeMap, reusing existing code and approaches wherever possible. Together with the OTFN incubator project from WP6 T1, work has started to prototype an installation and verify on the field thanks to a pilot link between PSNC in Poznan, Poland and Physikalisch-Technische Bundesanstalt (PTB, the German national metrology institute) in Braunschweig, Germany.

2.5 WiFiMon

WiFiMon is a crowdsourced, distributed, Wi-Fi network monitoring and performance verification system. It can detect performance issues, visualise the workload of the network, and provide technical information about the Wi-Fi network such as signal strength, link quality, bit rate, etc. WiFiMon leverages well-known performance verification tools (e.g. Akamai Boomerang, Speedtest) and in addition, uses data from the Wi-Fi physical layer in order to gather a comprehensive set of Wi-Fi network performance metrics.

Through JavaScript code that is installed on destination sites commonly visited by users (e.g. a college email website or intranet home page), performance measurements are realised when users access the website. This light-touch, distributed and crowdsourced approach requires no client software or applications, while significantly increasing the number of measurement points across the campus. WiFiMon is ideal for large-scale campus implementations and is fully compatible with eduroam services. An example dashboard of WiFiMon is shown Figure 2.5.

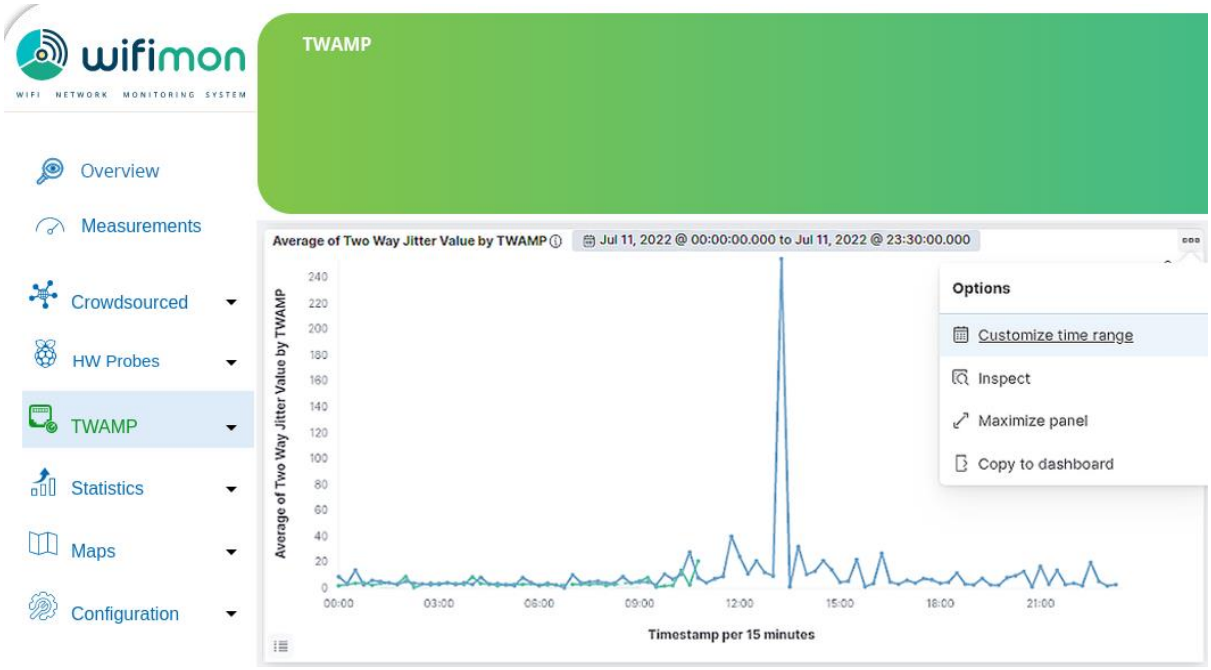

Figure 2.5: WiFiMon UI showing a spike in the TWAMP metric

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-premises. 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 be used on the NMaaS infrastructure, with the rest of the system still installed on-premises. 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-premises installation.

WiFiMon can be adopted by organisations for their own infrastructure, or potentially used where they offer Campus Network Management as a Service (CNaaS) services. Another use case where WiFiMon can be very beneficial is when 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 for any number of equipment vendor types. As such, it can also be used at conference or meeting venues, or other ad hoc, temporary Wi-Fi deployments where full control of the infrastructure might not be available.

From GN5-1 WiFiMon has six new users: three NRENs: ASNET-AM in Europe (Armenian NREN), RENU from Uganda and RNP from Brazil, CERN, a Brazilian University (Unicamp) and a German corporation SIB Systems.

2.5.2 Key Performance Indicators

The key performance indicators for WiFiMon are shown below in Table 2.6.

KPI	Baseline (start of GN5-1)	Target (end of GN5-1)	Achieved Result (end of June 2024)
Number of software releases per year	N/A	3	2
Number of dissemination activities/assisted organisations	N/A	15	16
Number of installations	3	5	9

Table 2.6: WiFiMon KPI targets and results for the period 1 January 2023 to 30 June 2024

2.5.3 Activities

The WiFiMon team released three new releases since the start of GN5-1: 2.0.0, 2.0.1 and 2.2.0. These versions included improvements in the automation of probe configuration, inclusion of ping and Network Time Protocol (NTP) statistics, estimation of the number of users connected to the Wi-Fi network and detection of anomalies in performance measurements through an implementation of the Hampel Filtering statistical method. Code quality has been addressed following WP9 review, an automatic count of active WiFiMon instances has been introduced and support to the new user organisations has been provided.

The WiFiMon team also focused on service promotion. In collaboration with WP2, a new promotional leaflet [WiFiMon_Leaflet] and an animated gif [WiFiMon_GIF] were created, and changes to the public-facing wiki pages were made.

WiFiMon dissemination activities included:

- A presentation at the RIPE #86 meeting, May 2023, Rotterdam, Netherlands [RIPE86].
- A lightning talk at the TNC23, June 2023, Tirana, Albania [TNC23].
- A blog post on the APNIC blog, August 2023 [APNIC].
- A CONNECT magazine article, October 2023 [CONNECT].
- A presentation at the Network Performance and Monitoring Workshop [NPMW], February 2024, virtual.

In October 2023, the team organised a full-day workshop in Yerevan titled Exploring Virtualisation and Monitoring Opportunities in Networking where participants explored virtualisation techniques and effective monitoring strategies while engaging in interactive exercises and demonstrations, giving them practical experience utilising WiFiMon [Virt and Monitoring WS]. Then in March 2024, an Infoshare [Infoshare WiFiMon] was organised to promote the service during which new user organisations (RENU, ASNET-AM and RNP) presented their WiFiMon deployment and use.

3 Conclusions

This document presented the production status of the five services offered by WP6 T3: Argus, perfSONAR, PMP, TimeMap and WiFiMon, providing updates on user adoption, passed and ongoing activities and KPI values after 1.5 years of activity in the GN5-1 project.

perfSONAR is the longest-running service of the network monitoring portfolio provided by the GÉANT project. In high-speed networks serving the research and education communities, ensuring bandwidth and latency expectations are reached is key for high-volume data transfers and low-latency real-time applications. perfSONAR keeps on fulfilling this role and is evolving with more openness to satisfy modern NOC needs.

New services like Argus and TimeMap are progressing well. The first has the potential to be used in many Network Operation Centers of the R&E community where, surveys have shown, alarms are coming from numerous and very different sources. There is a growing need to gather all these alarms in a single place for easier display and management. The latter is helping observe networks for latency issues that can cripple the performance of applications. Its deployment model, quite different from the perfSONAR one, enables monitoring latency and jitter on specific network segments, splitting up the end-to-end monitoring already provided by perfSONAR and therefore helping in pinpointing the exact place where the performance degrades.

When Wi-Fi networks are ubiquitous on campuses and students, researchers, academics, and other working individuals are using this media from different devices all day long, there is WiFiMon to help ensure quality connections are provided. This tool keeps being used by organisations of different sizes in Europe and worldwide.

Four of the services offered are based on software developed by the GÉANT project, usually in collaboration with its partners: Argus, perfSONAR, TimeMap and WiFiMon. They are complementary, fulfilling different needs and giving a different monitoring view of the network and its performance. The latest efforts in perfSONAR development to migrate to an OpenSearch backend and a Grafana frontend alongside the addition of new glue services for Argus give versatile tools able to adapt to the different needs of our diverse community, thereby providing robust platforms that can serve as integration point, or for being integrated, in already existing and deployed solutions. This openness and flexibility are qualities that WP6 T3 seeks in the future.

The fifth service, PMP, is more operations-based. As a platform, it provides a place to demo and deliver hands-on experience for the other services to its users while also giving WP6 T3 a direct opportunity to be confronted with the pitfalls and shortcomings of the developed solutions thereby returning first-hand actionable feedback. Deploying and operating perfSONAR in such a heterogeneous environment has given insights and expertise directly valuable to the perfSONAR development team and the consultancy and expertise subtask.

The TimeMap architecture and visualisation model inspire other monitoring use cases. The ongoing work on building an OTFN monitoring map based on it is promising and shows that expertise acquired in one specific area can directly benefit others. The research and development effort done in identifying measurement anomalies through the use of machine learning techniques and statistical models, as pursued with PMP, TimeMap and WiFiMon datasets, is another area where new expertise has the potential to be reused and spread to other services.

The KPI of the different services are looking good and the user adoption is stable where it does not keep increasing. Surveys and use show the services are satisfying user's needs and there is also continued progress in providing documentation and training so that access is facilitated.

With such a portfolio and development opportunities, the GÉANT project continues to provide monitoring services that are useful and used by its members and throughout the R&E community. WP6 T3 is already engaged and will continue to deliver the quality and effectiveness currently provided, while looking at new ways to combine metrics and measurement sources for more integrated monitoring solutions in the future.

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Glossary

CNaaS	Campus Network Management as a Service
KPI	Key Performance Indicator
L2, L3	Level 2, Level 3
MP	Measurement Point
NOC	Network Operations Centre
NREN	National Research and Education Network
NTP	Network Time Protocol
OFTN	Optical Time and Frequency Networks
PERT	Performance Enhancement Response Team
PMP	Performance Measurement Platform
R&E	Research and Education
TWAMP	Two-Way Active Measurement Protocol
WAS	WiFiMon Analysis Server