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PIONIER OAV Architecture Analysis White Paper

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Abstract

The document analyses the mapping of the network architecture of the Polish Optical Internet (PIONIER) - a nationwide broadband optical network for e-science to the TM Forum's Open Digital Architecture (ODA). This analysis is one of a series of such documents aiming to provide a standardised view of the components and implementations of orchestration, automation and virtualisation (OAV) within the NRENs.

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Executive Summary

Analysing National Research and Education Network (NREN) architectures from an orchestration, automation and virtualisation (OAV) point of view using a common reference architecture helps align efforts between the NRENs, and find similarities in the way different functionalities and components are implemented, which in turn facilitates potential collaboration and future interoperability between organisations. In pursuit of this goal, the GN4-3 Network Technologies and Services Development Work Package (WP6), Network Services Evolution & Development Task (T2) selected the TM Forum Open Digital Architecture (ODA) as a reference blueprint architecture that can be used for such cross-comparison. The rationale for that choice is described in Deliverable D6.6 Transforming Services with Orchestration and Automation [DEL].

The WP6T2 team is working with NRENs to perform such mappings. In this document, the team reports on an analysis of the different functional aspects of the PIONIER network architecture, managed by the Poznań Supercomputing and Networking Centre (PSNC). The document focuses on PSNC networking activities, and analyses how different components map to the ODA reference model. The mapping highlights the main characteristics and capabilities of the current PIONIER network architecture, and how they fit into the main functional domains of ODA. The analysis was carried out by the PSNC network architects supported by the WP6T2 team.

1 Introduction

PIONIER is the Polish National Research and Education Network operated by the Poznań Supercomputing and Networking Centre (PSNC) [PIO]. It provides a network infrastructure for the Research and Education Community in Poland. PIONIER's direct customers are the 21 Metropolitan Area Networks – members of the PIONIER Consortium. All education and research end-user institutions are connected via Metropolitan Area Networks, and not directly served by PIONIER.

Figure 1.1: The PIONIER network in Poland

Figure 1.1. Currently, the PIONIER network uses two optical Dense Wavelength Division Multiplexing (DWDM) transmission systems:

- The first provides functionalities such as directionless, colourless, and contentionless DWDM. This system allows running up to 80 x 10 Gbps optical channels on one pair of optical fibres, and it includes direct 10 Gbps optical connections (primary and backup connections) from MAN centres to two routers in Poznań for international connectivity services.
- The second is a new infrastructure in the PIONIER network which comprises 100 Gbps connections between HPC centres, as well as MPLS connectivity for which a full mesh topology was used.

The entire PIONIER network is built using Juniper core routers. In addition, there is a 100 Gbps access network to High Performance Computing (HPC) resources for MAN networks connected via 100 Gbps channels to the HPC backbone nodes. This 100 Gbps network is also used for international connectivity to AMS-IX, DE-CIX, LINX, GLIF, NORDUnet, GÉANT Open, and CERN.

Although PIONIER does not provide a formal, publicly available service catalogue, the basic set of networking services available for its users includes:

- Fibre infrastructure lease
- Spectrum lease
- L2 Virtual Private Network (VPN) circuits
- L3 VPN circuits
- GÉANT access
- Global Internet access
- Internet exchange access

The initial service pack for all members is oriented towards GÉANT connectivity and internet access, while additional services (eg. fibre lease) require an additional subscription and payment. However, most services that are available via PIONIER are bespoke, and specifically designed for the needs and purposes of a given customer. For these, all technical details and Service Level Agreements (SLAs) are negotiated between PSNC and the customer before service implementation.

PIONIER network management is distributed between three teams:

- The Network Operations Centre (NOC), based in Poznań, is responsible for the optical and MPLS layers. It also serves as the PIONIER helpdesk.
- IP NOC, based in Łódź, is responsible for the IP layer only.
- Operations, is in charge of service provisioning, reconfiguration, service upgrades, and similar on-demand activities.

One of the goals of this document is to identify all software components and tools used for PIONIER network management and try to map them to the corresponding Open Digital Architecture functional domains in order to provide a standardised view of PSNC's systems used to manage PIONIER.

2 Workflow Analysis

PIONIER's current Business and Operation Support System (B/OSS) consists of several components that are a mixture of commercial and open-source modules.

The following steps present an order to fulfilment workflow that describes the process of how a requested service is provisioned in the PIONIER network:

1. Request for information: A customer expresses an interest in a PIONIER network service such as a new VPN, lambda, or p2p connection.

2. Service specification: Although there is a standard basic set of available network services, in most cases the interest is in a specialised, bespoke solution that is tailored to specific customers and their current network configuration. Therefore, the specific requirements are discussed with the NOC members, and the new service parameters are defined.

3. Service ordering: The customer's known representative (contact person for PIONIER) sends an official order email to the Operations Team in PSNC, including the details required for the requested service.

4. Authorisation: Usually, orders are pre-authorised, but, in some cases, there may be a need for particular requests to be authorised by PSNC managers.

5. Provisioning: service requests and orders are currently not tracked via the ticketing system due to the low number of day-to-day requests. All activities related to service ordering and provisioning are coordinated by the Operations Team via email:

    a. There may be multiple teams involved in configuring the service depending on its scope (IP, MPLS, optical service, etc.).

    b. The customer is updated about the progress of provisioning the service via email.

    c. If the service requires changes in the IP layer, then a separate email request is issued by the Operations Team to the PIONIER IP NOC, an external party which is operated by another organisation within PIONIER.

    d. Service configuration in the PIONIER core is usually done manually using the Command Line Interface (CLI). Recently, some of the services and configuration snippets have been automated with Ansible.

6. Billing: In some cases, if the service has to be billed, it is also necessary to involve PSNC's accounting department in order to prepare contracts and agree billing details.

7. Monitoring: Once the Operations Team has configured and tested the service in the PIONIER core, the customer is informed, and the network monitoring configuration is updated:

    a. Monitoring is initiated either via an automatic (updated information fetched from a device) or a manual refresh of MRTG, Grafana, and Tivoli NMS configuration (this is done by the Network Management Team/PIONIER NOC).
    b. Where necessary, the NOC's documentation held in Atlassian Confluence is also updated upon information received from the Operations Team.

3 Introduction to ODA

PIONIER's OAV architecture analysis has been conducted using the TM Forum Open Digital Architecture's (ODA) [ODA] functional blocks as a reference point. The TM Forum ODA is promoted as a blueprint for new digital industry architectures, and the rationale for its selection as a reference model by the GN4-3 WP6T2 team is given in Deliverable D6.6 *Transforming Services with Orchestration and Automation* [DEL]. The ODA documentation set provides common terminology, a minimum set of core design principles, and groups of decoupled functionalities. Together they define the requirements for the implementation of an agile model-driven service management architecture that incorporates orchestration and automated operations - across both virtualised and hybrid environments.

The main idea behind ODA is component decoupling and integration. This enables an independent choice of solutions for each component while at the same time maintaining a unified overall approach that supports the full end-to-end service lifecycle (including interoperability). The high-level ODA functional architecture maps the main components by their capabilities to the ODA function blocks (see Figure 3.1).

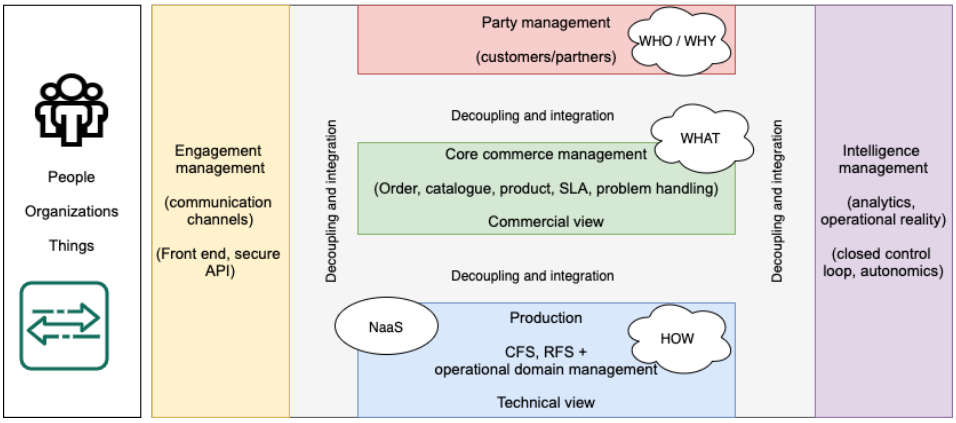

Figure 3.1: The TM Forum ODA functional architecture

In a nutshell:

- The Party Management functional block handles the processes that are related to all parties that interact with the organisation, defining their roles and relationships.

- The Intelligence Management functional block describes the implementation of data analytics processes and, based on an analysis of these processes, provides closed control loops for full automation wherever possible.
- The Core Commerce Management functional block focuses on the placement of products and services to the customers, and manages the product lifecycle.
- The Production functional block manages the delivery and lifecycle of all customer-facing and resource-facing services that can be based on different technologies or might be a combination of multiple operational domains, including multi-domain services provided in cooperation with other parties.

4 Mapping to the OAV Reference Architecture

Figure 4.1 illustrates how the service management components from the Business and Operation Support System that are used to manage the PIONIER network, are mapped to the TM Forum ODA reference architecture.

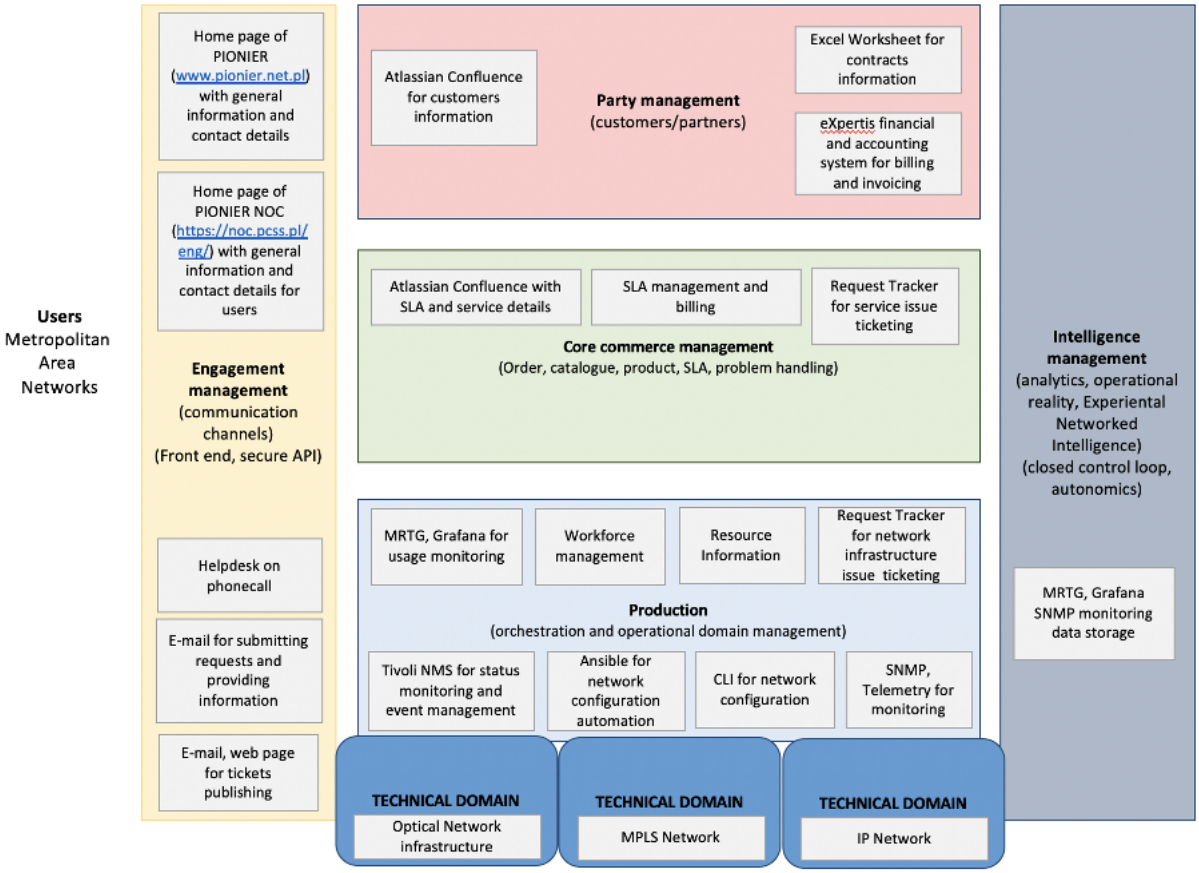

Figure 4.1: PIONIER service management components mapped to the TM Forum ODA

4.1 Engagement Management

The main components of the Engagement Management functional block of the PIONIER network are as follows:

- The home website of PIONIER [PIO]. It presents basic information about the PIONIER network infrastructure and related projects. It also provides news of recent activities (events, projects, achievements, etc.) and a set of contacts.
- The home website of the PIONIER NOC [NOC] provides information on how to contact the NOC in case there are any issues with the network services the PIONIER network offers. in addition, the site provides information regarding the procedures for defined events such as scheduled maintenance, co-location access for customers to PoPs, and related customer queries.
- The email communication channel. This is the primary means of communication with customers. They usually send email messages to request service provisioning or service modifications.
- The Helpdesk, available by phone or email. The PIONIER NOC staff offers 24x7 support to the customers via phone any time, every day.
- Email and a specialised web page are used for ticket publishing. Any ticket updates related to a service incident or a maintenance activity from Request Tracker [RT] are sent to dedicated subscribers depending on service or network areas. Some of these ticket updates may be internal PSNC communication only, while others may involve the customers and other related external parties. Public PIONIER tickets are published on PIONIER's web page [TIC].

4.1.1 Party Management

Within the Party Management block a couple of PIONIER components can be mapped:

- Atlassian Confluence, a collaboration wiki tool for storing information about customers and partners that is used by the PIONIER NOC (helpdesk) or network engineers (Operations Team). Within this block the wiki pages that include contact information are mapped, while the rest of the information is mapped to another block as presented in Figure 4.1.
- MS Excel worksheets are used by different groups to store contract information and billing data. They are commonly used as a supporting tool in the accounting office.
- eXpertis is an internal PSNC finance and accounting system that is used by the whole organisation. It is a quite isolated and tailored system that implements workflows for internal orders as well as processing incoming invoices.

4.2 Core Commerce Management

The PIONIER management functionalities that map to the Core Commerce Management block and are focused on providing end-user services to customers are represented by the following elements:

- Atlassian Confluence pages contain information about service instances, i.e. established network services, service details, and their respective SLAs agreed with the customers.
- Request Tracker is used as a ticketing system by the PIONIER NOC. This tool is used to track the whole ticket lifecycle and helps follow the information and resolution progress on network and service incidents. The NOC operators and Operations Team members work on a 24x7 schedule.
- MRTG and Grafana are used to create periodic reports used for some customers' SLA verification and billing. A customer report usually contains a set of graphs that present access interface utilisation, a list of tickets with corresponding details like outage times and root cause, access link availability, and a summary of network changes. Depending on the SLA, it may also contain 95th percentile information.

4.3 Production

The PIONIER B/OSS components that offer functionalities mainly mapped to the Production functional block are as follows:

- CLI for network configuration currently is the preferred way of network element configuration. For larger deployments in the core, some tasks are automated using custom Python scripts. Additionally, for some static config elements other scripts are used to push Jinja templates-based configurations to the network devices.
- Ansible is used to automate two types of actions:
  - Regular fetching of the advanced monitoring data from the core routers and storing it in a database.
  - Regular updating of BGP filters on the routers based on RIPE registry information.
- Resource Information - complete information about the resources of the PIONIER network is maintained by the Network Management Team / PIONIER NOC (documentation and Atlassian Confluence).
- Request Tracker is used to receive reports of issues in the network infrastructure, and track actions taken to deal with them.
- For network monitoring, MRTG and Grafana are used to collect, store and present historical network usage data. Tivoli NMS (IBM Netcool Network Management) is another tool that processes all events coming from PIONIER network devices. It is also used for active SNMP or ICMP polling.
- Streaming telemetry is used for additional monitoring and measurement data collection from interface queues on all Juniper routers, and helps to detect errors as well as observe trends. Junos Telemetry Interface [JTI] streams the data with the use of a Google protocol buffer to a dedicated central VictoriaMetrics [VMD] Database. The PIONIER network's Network

Management Team and Operations Team can then use this data for visualisation within the Grafana tool and Mattermost IM application. Grafana also generates alarms when the thresholds established for certain parameters are violated.

- Workforce management - the NOC operators and Operations Team members work on a 24x7 schedule.

4.4 Intelligence Management

- MRTG and VictoriaMetrics RRD files that are integrated with Grafana are used for long-term storage of monitoring data, and future data analysis. In selected service scenarios, threshold monitoring is used to track specified service conditions. However, with the exception of alarms, there are no automation tools that are used for common data analysis, and processing is done on an ad-hoc basis.
- Selected datasets can be used (with the permission of PSNC management) for testing and analysis by research projects working on Artificial Intelligence/Machine Learning solutions.

5 Experience and Evolution towards Enhanced OAV Implementation

The strategic approach to the evolution of the PIONIER network management components and processes is based on implementing best practices and lessons learnt from various projects and initiatives that have been implemented by PSNC engineers. In this way, only well-tested and proven approaches are chosen to be integrated into PIONIER, avoiding compromising its reliability and stability.

PSNC is involved in research projects in which various OAV tools and solutions are being tested to verify their potential and added value for implementation in the PIONIER network. In this section, a handful of examples are presented that are currently under investigation for reuse in PIONIER.

One of the initiatives is the team working in the GÉANT GN4-3 project and its OAV group (Work Package 6 Task 2) that has designed and implemented the Service Provider Architecture Platform [SPA]. This software follows the design principles and standards proposed by the TM Forum, helping to build flexible and open service management systems. SPA is already deployed in the GÉANT network to manage the production GÉANT Connection Service (GCS), enabling automated provisioning of end-to-end circuits.

At the moment, the PIONIER network engineers are interested in using one of the SPA components, the SPA Inventory, that enables storing information about any type of infrastructure resource and is managed via an open REST API. This component is being tested as a potential single source of truth for an automated network configuration service. Moreover, it is considered that this application will be used as a source of topology data for Ansible and thus improve and extend automated operations in PIONIER. In the long term, other SPA components such as Customer Relationship Management (CRM), Order Management or Orchestrator, as well as the integration approach based on open APIs and processes will be taken into account as potential candidates to improve or enrich the services in the PIONIER network.

Apart from SPA, the GÉANT GN4-3 project also works on the development of the Network Management as a Service (NMaaS) platform [NMS]. This platform aims to provide a network management application packed in containers that can be run as a dedicated per-user instance in a cloud environment. The PSNC software engineers are directly involved in this initiative, and one of the NMaaS instances is deployed on PSNC resources. Potential use cases and benefits for PIONIER network services are being investigated, but it is worth mentioning that NMaaS is based on the newest automation and virtualisation solutions like Kubernetes and CI/CD tools and procedures, and the knowledge and experience gained from operating these is used to design new services in PIONIER.

The PIONIER network provides many opportunities for researchers as a vast source of network data is collected on a daily basis from different types of resources. PSNC utilises this data for the analysis of specific network behaviour, and to improve the performance of the infrastructure.

The NREN is also working on projects that aim to develop new data monitoring and analysis tools. An example of such activities is the Intelligent Platform for Anomaly Detection (IPA) project [TNC] that has developed a platform for:

- automated network anomaly detection with the use of machine learning algorithms and vast volumes of monitoring data, and
- execution of appropriate actions, for example, reporting attacks or threats, and dynamic creation of firewall rules in appropriate locations in response to those.

The IPA software is composed of a few independent but well-integrated components. One of them is StackStorm, a well-known orchestrator that has been used to manage the processes. Another component is the popular Slack IM client application that is used to interactively talk to the IPA platform and execute actions.

6 Conclusions

The mapping of the PIONIER network management system against the TM Forum Open Digital Architecture (ODA) presented in this document shows how elements of the network management system (NMS) fit into functional blocks of the ODA. This enables comparison of the PIONIER solution with other NMS solutions, either from standardisation bodies or architectural solutions available on the market, or those from other NRENs in the GÉANT community, paving the way for better understanding of implemented solutions and/or for future collaboration.

The PIONIER core network that interconnects all R&E MANs in Poland must offer stability to its users in addition to the bandwidth capacity they need. Therefore, robustness, stability and 99.999% availability are the goals that PIONIER network engineers must accomplish in their day-to-day management activities.

As PIONIER's network management systems evolve to offer new services and adapt to user demands, they are upgraded only after careful analysis and thorough testing. This enables the gradual introduction of OAV solutions in the PIONIER production workflows, where only stable and verified technologies and tools are considered. Currently, the focus is set on the introduction of Ansible for repetitive tasks automation together with automated telemetry solutions that enable deeper insight in the network monitoring data.

The large variety of OAV-related research projects that the PSNC network engineers are involved in serve twofold towards these goals:

- They can be used as testbeds to learn, analyse, and test the new technologies and current trends in automation and orchestration, so that well-informed decisions can be made and only stable solutions are adopted in PIONIER.
- They serve as a playground where network engineers can enhance their OAV skills, and produce documented best practices and lessons learnt, based on which the evolution and future design of PIONIER can be developed.

The GÉANT project and its support of the development of a tight-knit NREN community provides additional leverage towards this goal by promoting knowledge exchange that can help the NRENs share their experiences and help each other on their OAV journeys.

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Glossary

API	Application Programming Interface
B/OSS	Business/Operations Support System
BGP	Border Gateway Protocol
CI/CD	Continuous Integration / Continuous Deployment
CLI	Command Line Interface
CRM	Customer Relationship Management
DWDM	Dense Wavelength Division Multiplexing
GCS	GÉANT Connection Service
HPC	High Performance Computing
ICMP	Internet Control Message Protocol
IM	Instant Messaging
IP	Internet Protocol
IPA	Intelligent Platform for Anomaly Detection
MAN	Metropolitan Area Network
MPLS	Multiprotocol Label Switching
NMaaS	Network Management as a Service
NMS	Network Management System
NOC	Network Operations Centre
OAV	Orchestration, Automation and Virtualisation
ODA	Open Digital Architecture
p2p	Point-to-point
PoP	Point of Presence
PSNC	Poznan Supercomputing Networking Centre
REST	Representational State Transfer
RRD	Reduced Resolution Dataset
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SPA	Service Provider Architecture
T	Task
VPN	Virtual Private Network
WP	Work Package