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Switch OAV Architecture Analysis

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Abstract

This document analyses the mapping of the Switch architecture to the TM Forum's Open Digital Architecture (ODA), aiming to provide a standardised view of the components and implementations of orchestration, automation and virtualisation within the NREN.

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Executive Summary

Analysing National Research and Education Network (NREN) architectures from an Orchestration, Automation and Virtualisation (OAV) perspective 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.

The TM Forum Open Digital Architecture (ODA) is being used as a reference model to map several architectures in the GÉANT project. Mapping the architectures to a single blueprint makes cross-comparisons easier and helps organisations working on digital transformation. A reference architecture like ODA supports the transition from traditional modes of organisation based on manual work and procedures to a model where services are automatically provisioned and orchestrated.

This document presents the mapping of the main components at Switch, the Swiss NREN, onto the ODA functional blocks of Engagement Management, Party Management, Core Commerce Management, Production, and Intelligence Management, demonstrating how Switch's architecture supports modularity, scalability, and end-to-end service lifecycle management.

Switch's approach is deeply rooted in collaboration with the academic community. The Switch LAN network spans 3,100 km of fibre-optic backbone and delivers bandwidths up to 400 Gbps. This network forms the foundation for a wide array of services, including cloud computing, federated identity management, and cybersecurity.

Its services, such as Switch Cloud and Switch edu-ID, are designed to meet the evolving needs of research and education while ensuring data sovereignty and compliance with Swiss data protection laws. The organisation's emphasis on security is demonstrated by its CERT tools and monitoring systems, which provide incident response, forensic analysis, and continuous network performance oversight.

The ODA architecture analysis in this paper shows that Switch integrates robust infrastructure, community-driven service development, and a modular architecture aligned with ODA principles. Its secure, scalable, and innovative services position it as a key enabler of digital transformation within Switzerland's research and education landscape.

1 Introduction

Switch was established in 1987 as a private foundation by the Swiss Confederation and the eight cantonal universities that existed at the time. The key aspects of the Switch Foundation's mission are to enable and continuously expand a secure and networked research and education (R&E) infrastructure in Switzerland. This mission drives the NREN to new innovations day after day to the benefit of all students, lecturers and researchers across the country, and ultimately Switzerland itself as an increasingly digital centre of business. Switch creates services by integrating core competencies and working closely with the community. With its collaborative network, Switch promotes active knowledge sharing and joint service development. As a non-profit foundation, Switch does not aim to maximise profits. This means Switch can balance the interests of all stakeholders and offer the greatest possible benefit to the R&E community.

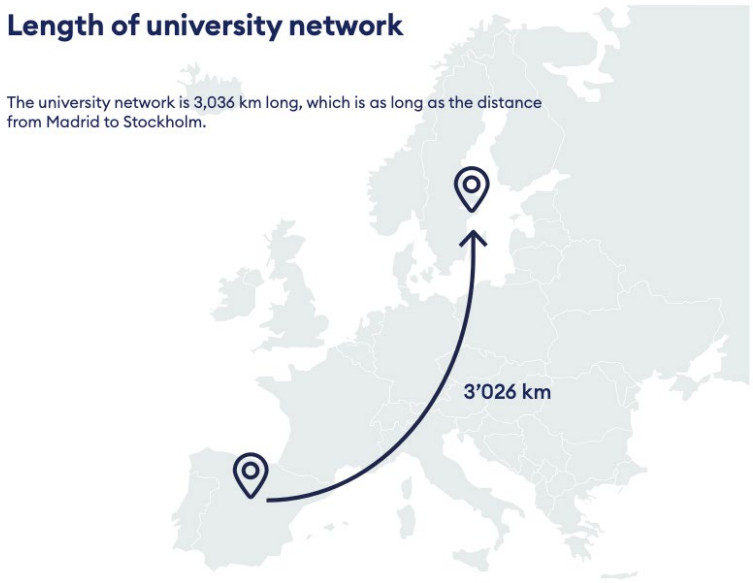

Figure 1.1: The length of Switch's university network

Despite the name, Switch LAN [1] is a cross-country IP network, delivering much more than a traditional local area network (LAN). It represents a unique combination of infrastructure, transmission technology, quality assurance, laboratory facilities, support and transparency. Switch LAN connects universities and research institutions across Switzerland, providing them with reliable internet access and seamless integration into global academic networks. The Switch LAN network is built on a fibre-optic infrastructure spanning approximately 3,100 km. It offers high-performance connectivity with bandwidths ranging from 10 to 400 Gbps.

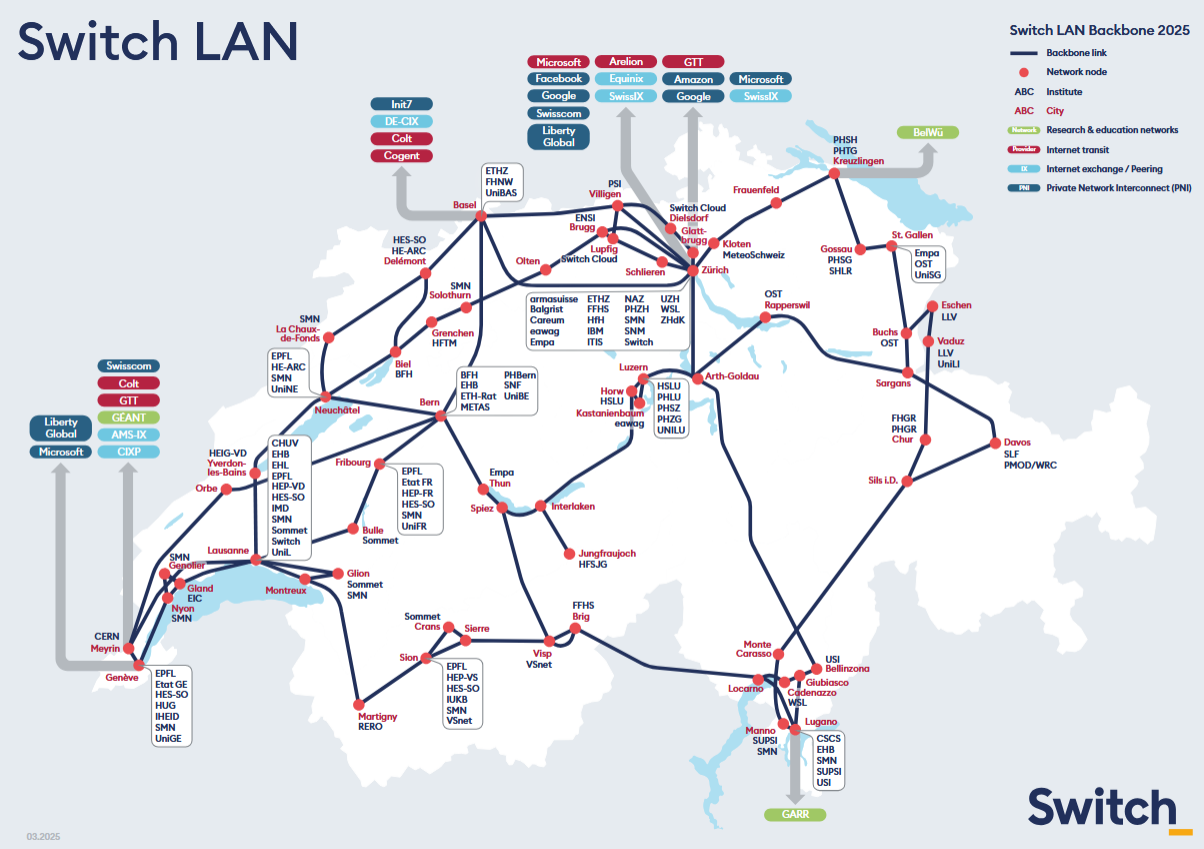

Figure 1.2: The Switch LAN backbone infrastructure

TM Forum Open Digital Architecture

Switch's OAV architecture analysis has been conducted using the TM Forum Open Digital Architecture (ODA) functional blocks as a reference point [2]. 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 Network eAcademy team of the Network Development work package (WP6) of the GN5-2 project is given in GN4-3 Deliverable D6.6 *Transforming Services with Orchestration and Automation* [3]. The ODA provides common terminology, a minimum set of core design principles, and groups of decoupled functionalities. Together, these define the requirements for the implementation of an agile, model-driven service management architecture that incorporates orchestration and automated operations, as well as virtualised or hybrid environments.

The main idea behind ODA is the decoupling and integration of components, which 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 into the ODA function blocks (see Figure 1.3).

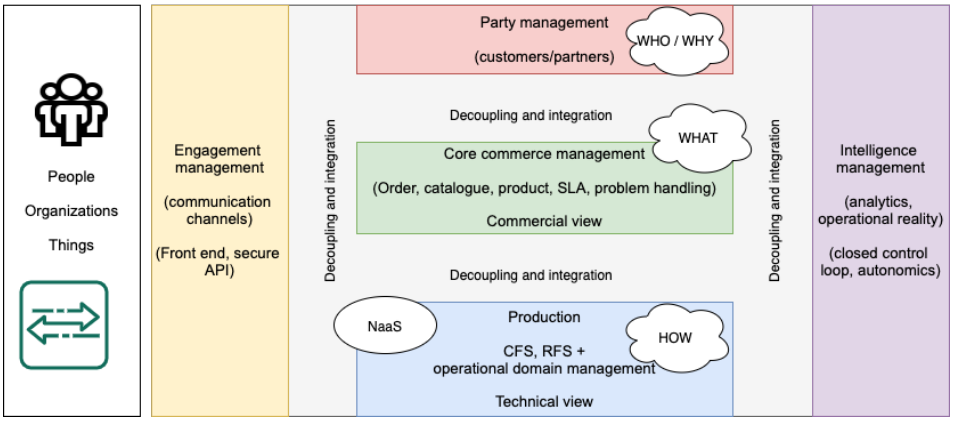

Figure 1.3: The TM Forum ODA functional architecture

In a nutshell:

- The **Engagement Management** functional block focuses on engagement with the end-users (people and systems) that can interact via multiple channels.
- The **Party Management** functional block handles the processes related to all parties that interact with the organisation, and defines their roles and relationships.
- The **Intelligence Management** functional block covers the implementation of data analytics processes, and based on the analysis, 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. These can be based on different technologies or might be a combination of multiple operational domains, including multi-domain services provided with the cooperation of other parties.

2 Architecture Analysis

This section provides a high-level approach to the OAV Architecture analysis, followed by the mapping of individual operational systems to the blueprint architecture of TM Forum ODA.

2.1 High-Level OAV Approach

Since its foundation, Switch has connected the university landscape with the infrastructure necessary for research and education. By linking universities to one another and to the internet through the advanced Switch LAN network, Switch ensures reliable and efficient connectivity. Beyond providing the network, Switch also delivers the tools and resources essential to R&E, empowering institutions with a comprehensive digital foundation.

Good enough for every application and always available – the standards for a communications network have hardly changed in decades. However, what is evolving rapidly is the variety of applications and the performance of users' machines. This continuous advancement presents new challenges for networks. When Switch LAN was launched in 1989, the maximum connection bandwidth was just 128 kbps, which was enough for all applications at the time. Since then, it has grown to 400 Gbps, which is sufficient for all current applications – at least for now.

Switch LAN is more than a well-functioning data network for universities. It is a unique combination of infrastructure, transmission technology, quality assurance, laboratory, support, transparency and partnership. To ensure universities make the most of the network, Switch complements its infrastructure with valuable network services and dedicated, expert customer support.

Switch is part of the university community and puts its resources at the service of innovation. This also means that the Switch LAN team is open to experimental projects. As a result, Switch LAN is the base service for many central Switch services such as Switch Cloud and Switch edu-ID.

Swiss universities participate in the Switch edu-ID identity federation, which is orchestrated by the Switch Foundation. Within the federation, members of universities can access the services of other universities using their Switch edu-ID login. All personal data remains in Switzerland under the direct control of Switch and the universities and is covered by Swiss data protection provisions.

Powered by the resilient OpenStack framework, Switch Cloud offers a versatile and dependable platform for virtual machines (VMs), purpose-built to handle the dynamic demands of universities and research institutions.

2.2 Mapping to ODA Functional Architecture

Put into context of the TM Forum ODA functional representation [4], Switch's Network Management System (NMS) architecture components can be represented as in Figure 2.1. The grey boxes in the diagram represent Switch's the NMS architecture components, and their placement within the ODA functional blocks is based on their main functionalities. The blue boxes represent Switch products (tools) which are explained in more detail in this document. Where applicable, in the following figure, those blue boxes are placed within bigger grey boxes that represent technical domains.

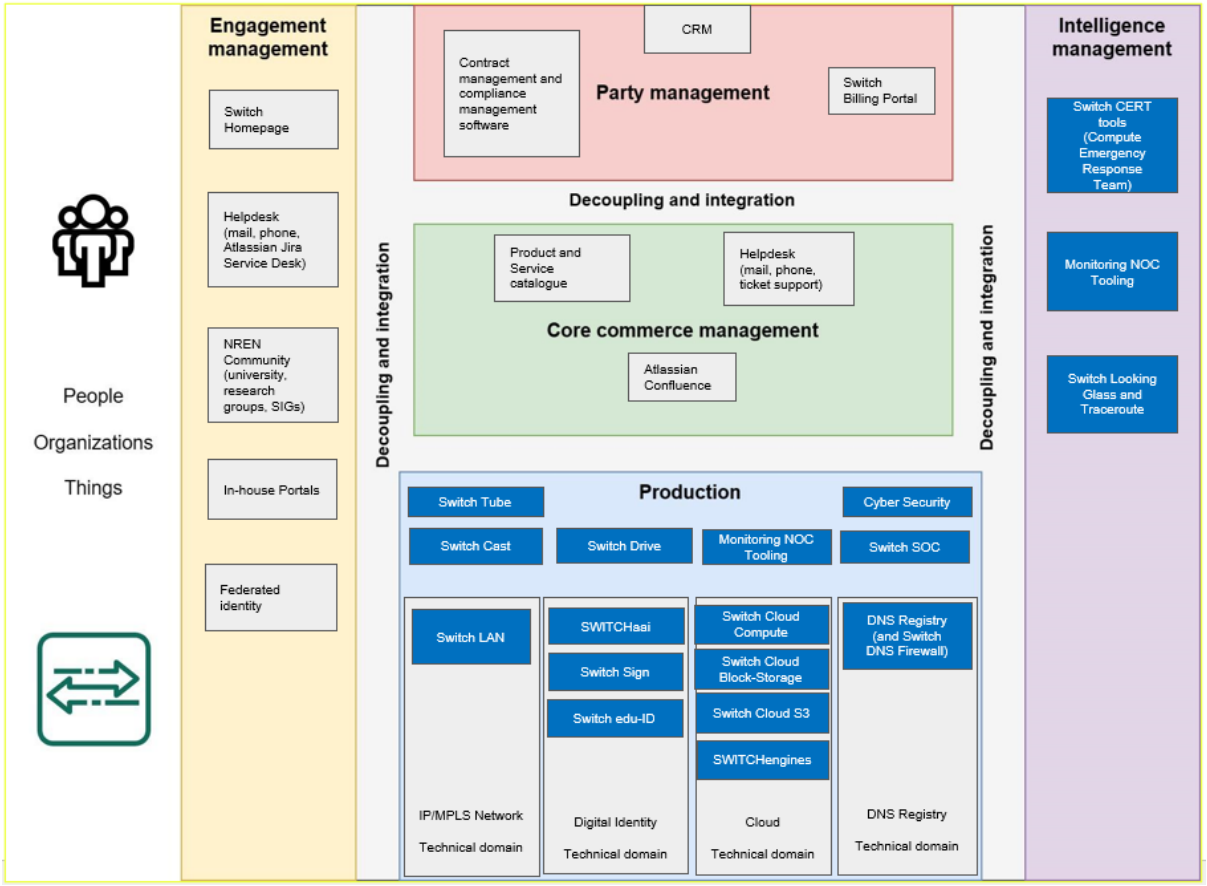

Figure 2.1: Switch's NMS components mapped to the TM Forum ODA

2.2.1 Engagement Management

The Engagement Management functions, as outlined in the ODA framework, focus on the channels of interaction and communication through which users can access services and support. Switch uses an array of tools for engagement management, from the Switch homepage, the helpdesk, traditional phone calls and e-mails to more advanced in-house portals and the wider NREN community. The functionalities of each are briefly explained below:

- **Switch homepage** – Provides information about Switch competencies, services, policies, communities, marketing, etc [5].
- **Helpdesk** – Switch staff offer service-based support via phone and mail (integrated into the OTRS ticketing system). An implementation of Jira Service Desk is underway.
- **In-house Portals** – Some services like SWITCHengines have self-service Portals where customers can utilise services according to their own need.
- **NREN community** – Many teams in Switch regularly participate in relevant community events, and the NREN has a Community Manager responsible for, among other things, engaging with parties from communities of interest.
- **Federated identity** – Switch edu-ID [6] is the universal login for lifelong learning, providing students and other users access to thousands of national and international services. Switch edu-ID is an authentication system with a single identity for accessing academic services from any university that is a member of the Switch edu-ID federation [7]. Its objective, in a nutshell, is to simplify inter-organisational access to web resources. It is deployed by most Swiss universities. With a single login a student can access e-learning systems at any participating university, among other things. The Authorisation and Authentication Infrastructure (AAI) makes use of a concept called Federated Identity Management.

2.2.2 Party Management

Party Management functions concentrate on managing information and relationships relating to both current and potential customers. These functions are mainly handled through the following tools:

- **Contract management and compliance management software** – used for:
    - Central storage of contracts.
    - Workflows for review and approval of contracts.
    - Management of templates.
    - Creation of drafts during contract negotiations.
    - Monitoring of deadlines and contract fulfilment.
    - Electronic archiving.
- **Customer Relationship Management (CRM) solution** – responsible for:
    - Recording all customer relationships (B2B) in a systematic and structured way.
    - Partner and supplier master data.
    - Offering a single source of truth on organisation names and abbreviations, as well as address data.
- **Switch Billing Portal** – Switch Billing Portal is used to manage billing details, and is part of the Switch Cloud Portal that serves as the centralised platform for managing the cloud services provided by Switch.

2.2.3 Core Commerce Management

Switch uses a variety of tools for core commerce management. These tools are used to track service requests and manage the product catalogue. This functional domain is centred around overseeing customer interactions and ticketing systems. A summary of the tools used is provided below:

- **Product and service catalogue** – The Switch website [8] is in part a product and service catalogue; however, many services also have their own portals, as follows:
    - Switch CERT
    - Switch Security Awareness
    - Switch DNS Firewall
    - Switch Community Security Operation Centre
    - Switch Cloud Compute
    - Switch Cloud Block-Storage
    - Switch Cloud Kubernetes
    - Switch Cloud S3
    - Switch Drive
    - Switch Tube
    - Switch Cast
    - Switch Backup
    - Legal & Procurement
    - Switch Legal
    - Switch Procure
    - Switch edu-ID
    - Switch Sign
    - Switch Verify
    - Switch Portfolio
    - Registry Schweiz
    - Registry Liechtenstein
    - Switch LAN IP Access
    - Switch LAN L2VPN
    - Switch LAN SCION Access
    - eduroam
- **Helpdesk** – Switch staff offer service-based support via phone and mail (integrated into the OTRS ticketing system). An implementation of Jira Service Desk is underway.
- **Atlassian Confluence** – Atlassian's Jira and Confluence are used to support collaboration, project management, and software development.

2.2.4 Production

Some tools under the Production block are also used in other blocks. These are the main components used by Switch, together with a brief explanation of their use cases:

- **Cyber Security** – Switch's Computer Emergency Response Team (CERT) protects Swiss higher education and other critical infrastructure from cyberattacks.
- **Switch Community SOC** – The Switch Community SOC provides a central competence centre for analysing and responding to security incidents.
- **Switch Cast** – Switch Cast is a dedicated video platform for Switzerland's R&E community.
- **Switch Drive** – A service that allows users to store, synchronise, and share their files with anyone they wish to grant access.
- **Switch Tube** – Switch Tube is a playback platform for all videos and the new video portal for the Swiss university community.
- **Switch LAN IP Access** – Switch LAN is more than a well-functioning data network for universities. It is a unique combination of infrastructure, transmission technology, quality assurance, laboratory, support, transparency and partnership.
- **Switch LAN L2VPN** – Based on Switch LAN, Switch offers high-quality Layer 2 virtual private network (L2VPN) solutions for site networking. Ideal for a simple, transparent connection between two locations, Switch's L2VPN service is a powerful and flexible solution for customers with specific needs where Layer 2 connectivity is essential. While IP connections have many advantages, there are situations where L2VPN connections, which have their own unique strengths, are indispensable.
- **Switch LAN SCION Access** – Switch LAN SCION Access combines the security, reliability and control of private networks with the flexibility of the public internet. Switch has supported SCION's development at ETH Zurich since 2015.

2.2.4.1 Technical Domains

Switch's Production domain can be divided into several broad technical domains that focus on different aspects of the NREN's activities:

- **IP/MPLS Network** – Switch LAN L2VPN's point-to-point connections are based on Ethernet-over-MPLS (EoMPLS) technology. This allows users to seamlessly connect two locations through a dedicated point-to-point connection. An EoMPLS connection works like a very long Ethernet cable between the two endpoints. The Ethernet packets are encapsulated with multiprotocol label switching (MPLS) and transmitted via the Switch LAN IP backbone. As a result, the connection automatically benefits from the IP layer's redundancies. Because data is transmitted unencrypted through an EoMPLS connection, it is important to ensure adequate security on the customer's end.

  One example product in the IP/MPLS Network technical domain is Switch LAN (the Swiss R&E network backbone). Switch LAN brings together universities and research institutions from all over Switzerland. Plus, with Switch LAN SCION Access, customers can ensure that their data is only transferred to the parts of the internet that they want it to reach. Additionally, Switch LAN L2VPN, based on Switch LAN, is a high-quality L2VPN solution for site networking. Ideal for a simple, transparent connection between two locations, it also offers flexibility and scalability for several locations.
- **Digital identity** – Switch offers smart digital identity functionalities for all university members and other users with wide applications at all Swiss universities and beyond. This digital identity never expires and supports lifelong learning. Switch's digital identity services guarantee that user data stays within Switzerland and is protected by the strict Swiss data protection laws [9]. Products in this technical domain include Switch Verify, Switch Sign, and eduroam.

- **Cloud** – With its wide range of data management services, Switch provides security and efficiency to the Swiss R&E community. Users can archive large amounts of data, ensure its reliability, and utilise the cloud for simple data storage. Switch is a trusted partner for cloud services, offering solutions like Coldstore [10], Backup, and Drive, which provide the highest levels of security and reliability. Switch Cloud is a new offering designed specifically for the Swiss education, research, and innovation system. It meets user-specific needs in terms of flexibility, security, and performance, all while being fully controlled by Switch. This cloud solution perfectly complements existing products, especially for applications dealing with highly sensitive data.

  Some products in the Cloud technical domain are:

  - **Switch Cloud Compute** provides the infrastructure to handle complex requirements through a scalable, secure, and cost-effective solution. It streamlines the management of VMs, offers extensive customisation, and safeguards data with advanced security measures.
  - **SWITCHengines** allows users to create and use VMs on the Switch cloud infrastructure. These virtual machines can be installed with most modern operating systems (Linux, BSD, Solaris or Windows-based).
  - **Switch Cloud S3** – Built on the robust Ceph storage system, Switch Cloud S3 is an object storage solution designed to seamlessly manage vast amounts of unstructured data.
  - **Switch Cloud Kubernetes (SCK)** offers Kubernetes management functionality designed specifically for R&E institutions. By leveraging automation, robust security, and user-friendly interfaces, SCK reduces operational complexity and costs.
- **DNS Registry** – As a registry, Switch manages all domain names (internet addresses) ending in .ch and .li on behalf of the Swiss Confederation and the Principality of Liechtenstein. Switch's many years of experience guarantees security and stability. Switch partners, known as Registrars, are responsible for selling the domain names.

  Besides DNS Registry, the NREN also offers Switch DNS Firewall, which prevents malware infections and phishing attacks, as well as helping to identify already infected systems.

2.2.5 Intelligence Management

Intelligence management tools and functions mainly concentrate on collecting, managing, and analysing operational data for network performance, capacity planning and troubleshooting. The following are the tools and functions used by Switch for intelligence management:

- **Switch CERT tools** [11]:
  - Incident response and coordination
  - Permanent monitoring of the network to identify security problems
  - Information on the latest security issues
  - Advice and advisories in emergency situations
  - Development of innovative security mechanisms
  - Forensic investigations
  - Security awareness
- **Monitoring NOC tooling** – Service monitoring and alerting needs are covered by Switch infrastructure tools such as Nagios, Munin, Prometheus and Grafana, along with network monitoring tools like Traffic Viewer. In some cases, these tools are enhanced with automated actions in order to meet defined criteria.
- **Switch Looking Glass and Traceroute** – Switch Traceroute determines the route a packet takes through the internet to reach its destination (similar to the CLI `traceroute` tool). Looking Glass enables execution of basic operational commands on Switch routers, such as `ping`, `traceroute`, etc.

3 Conclusions

The Switch approach to network management and service provision is built on several key components. Since its foundation, Switch has focused on creating and continuously expanding a secure and robust research and education infrastructure in Switzerland. Switch LAN connects universities across the country, supporting experimental projects and central products such as Switch Cloud and Switch edu-ID. Switch prioritises community benefits, fostering knowledge sharing and collaborative service development. This approach makes Switch a valuable collaborator for many stakeholders and strengthens its ties with the university community, enabling specialised products like Switch Cloud (OpenStack-based), Switch edu-ID, and Identity Federation services that support academic collaborations and lifelong learning.

In addition to its collaborative network, Switch offers a broad range of core services and tools, including network management, cybersecurity, cloud computing (SWITCHengines, Switch Cloud Compute, Switch Cloud Block-Storage, Switch Cloud S3, Switch Cloud Kubernetes), and Federated Identity Management (edu-ID). These services cover operational domains like IP/MPLS networking, digital identity, cloud services, and DNS registry management, all aimed at enhancing security, reliability, and flexibility while addressing the unique needs of Swiss universities. Lastly, Switch places a strong emphasis on security through its CERT tools and services, which include incident response, monitoring, forensics, and security awareness. Continuous monitoring ensures operational efficiency, and diagnostic tools like Switch Looking Glass enhance network operations.

In conclusion, Switch's approach integrates strong collaborative foundations, cutting-edge infrastructure, and a modular architecture aligned with ODA principles to meet the evolving demands of Swiss universities and research institutions. Through its secure, scalable, and innovative services, Switch remains a key player in the Swiss digital and educational landscape.

Glossary

AAI	Authentication and Authorisation Infrastructure
B2B	Business-to-Business
CERT	Computer Emergency Response Team
CLI	Command Line Interface
CRM	Customer Relationship Management
DNS	Domain Name System
EoMPLS	Ethernet over MPLS
IP	Internet Protocol
LAN	Local Area Network
L2VPN	Layer 2 VPN
MPLS	Multiprotocol Label Switching
NMS	Network Management System
NREN	National Research and Education Network
NOC	Network Operations Centre
OAV	Orchestration, Automation and Virtualisation
ODA	Open Digital Architecture
OTRS	Open-Source Ticket Request System
SCK	Switch Cloud Kubernetes
SNMP	Simple Network Management Protocol
R&E	Research and Education
VM	Virtual Machine
VPN	Virtual Private Network
WP	Work Package

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