FUJITSU

White Paper
Open Optical Transformation

Introduction

Navigating the transition from today's proprietary optical networks towards an open, automated network architecture is now within the reach of service providers. The rise of open standards, APIs and open-source reference platforms has accelerated innovation to drive more openness and automation into today's networks. However, open optical networks present new challenges in terms of network design, multi-vendor control, business processes and operational implementations. The fundamental building blocks required for operating the optical network have not changed, but the migration to open networking requires the service provider to reevaluate who should provide these building blocks. It may no longer be possible, or desirable for a single vendor to provide the complete solution, and in many cases, the service provider may want or need to provide specific components to achieve their goals and gain competitive advantage. This document provides an overview of the open optical ecosystem today, identifies key challenges to address in implementing open automated networks, and outlines some migration strategies available for open optical networking. Fujitsu's early adoption of flexible, modular optical hardware products and software control solutions based on open-source platforms provides a unique offering to achieve one's immediate needs for network infrastructure builds, while providing the flexibility to migrate to open networking based on one's unique business and technical requirements.

Open Optical Ecosystem

There is an increasing push towards enabling optical networks to become more open and automated. Some of the key aspects driving the need for open architectures are vendor interoperability, lower total cost of ownership (TCO), accelerated network innovation, faster service delivery and automated control. Multiple industry organizations are working towards a vision for open optical networks. Figure 1 shows a brief overview of the different activities in the open ecosystem as it relates to optical transport.

Fujitsu has been actively involved in many of these initiatives by adding support for, and contributing to, the development of open standards, including interface specifications, YANG data models, Open APIs and most notably the Open ROADM Multi-Source Agreement (MSA). Because there are multiple initiatives addressing disaggregation in optical transport, we believe there is a strong need for harmonization among them so that the industry can truly benefit from standardization of common models and APIs.

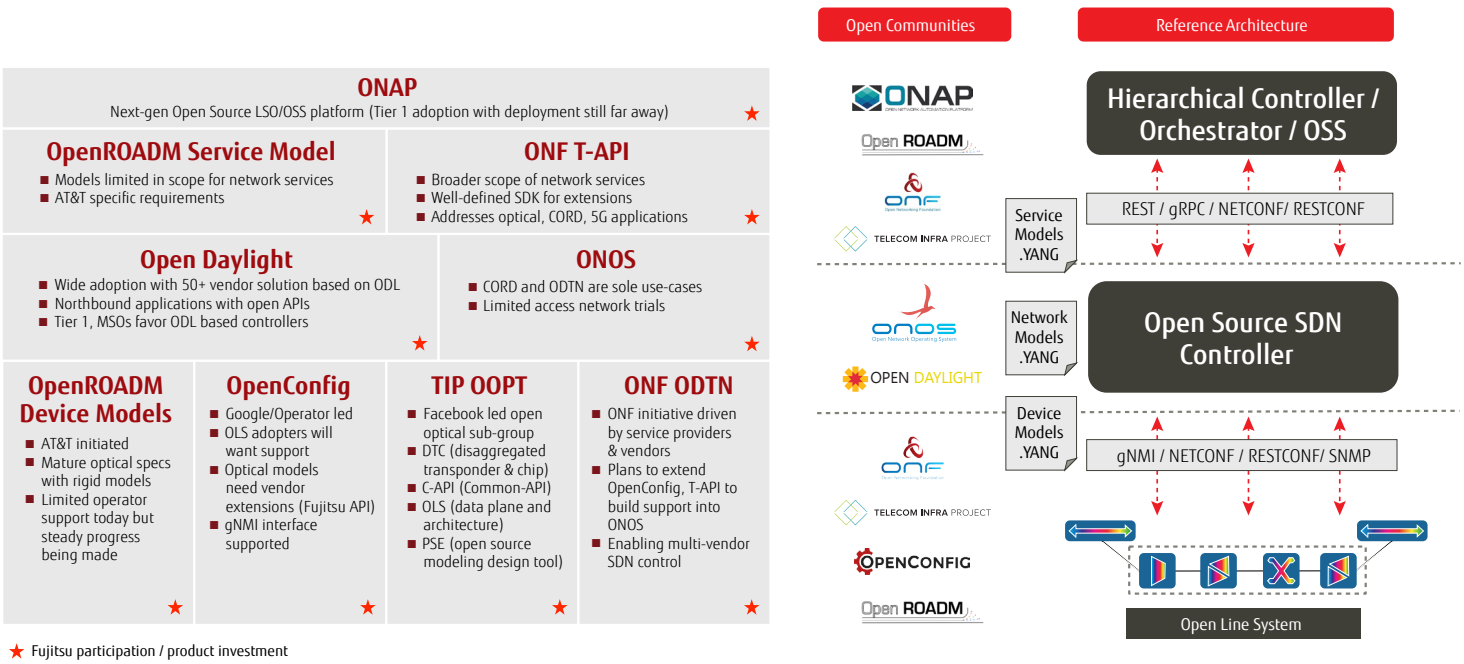


Figure 1: Summary of Open Initiatives

Navigating the Transition to Open

Transition Process Overview

As network providers shift to open networking, each operational building block of the migration must be considered, as well as the impact on organizations and systems, to enable seamless network introduction. Care must be taken to ensure that all stakeholder organizations are included in the migration, and that the introduction of replacement systems and workflows minimizes the impact to those organizations.

Successful transition planning includes:

- Assessment of high priority use cases to document necessary workflows for automation and interactions with human and network resources
- Assessment of the existing network management architecture to identify those systems and resources that will remain and those that will be eliminated
- Development of an OSS / Control architecture that retains key systems and introduces new systems and APIs for an integrated solution that provides the best return on investment
- Establishment of a deployment plan to include scenarios and timelines for implementation of systems, features and functions to the network

Challenges

As the value chain for optical networking is re-architected to enable openness, some key challenges are created with regard to the ownership and implementation of the network building blocks. These building blocks, such as network design, are fundamental and necessary to the deployment and operation of any network. However, the implementation of these building blocks must be carefully considered when deploying optical networks to ensure that one's implementation addresses the needs of all involved parties. Network planning will need to design and plan network capacity growth, and operations will need tools to analyze and operate the network. In addition, introducing multiple vendors' hardware into a common optical network creates new design and operational complexity, while also establishing a need to safeguard vendor intellectual property and competitive information.

Network Planning and Design

Some of the most important resources or services for network engineering and capacity management organizations are the Network Planning and Design tools. Proprietary tools are available with most ROADM solutions on the market today, and accurately characterize the capabilities of supported systems. However, transitioning to an open, multi-vendor environment requires an adaptation or re-architecture of these tools. The myriad combinations of vendor transponders and ROADM networks requires new approaches. Some of these include: (1) an open network design solution that protects vendor-confidential performance information needed for network design purposes; (2) offline network characterization tools and services that "prequalify" or estimate optical performance over ROADM infrastructure; and (3) closed-loop learning algorithms and solutions that optimize network design based on performance criteria and risk tolerance.

Capacity Management

Many of the same issues that affect multivendor planning and design also impact Capacity Planning and Management systems. These systems leverage detailed knowledge of both the ROADMs and transponders, and require accurate estimation of optical reachability among all potential endpoints on a ROADM network. Organizations responsible for Capacity Management use this information to plan service additions and infrastructure builds to ensure on-time delivery of end-customer services. As with Planning and Design tools, transitioning to an open, multi-vendor environment requires an adaptation or re-architecture of Capacity Management solutions. The information obtained from network design tools and services can be utilized for capacity management purposes using APIs to upload to the Path Computation Engine (PCE) and offline capacity management tools. It is critical that the same information and network/service inventory is available to all systems to ensure accurate records management and seamless automation.

Service Design and Activation

Similar to Network Design and Capacity Management, the design and activation of services over a multi-vendor, open network requires careful consideration and integration into any production architecture. With proper capacity management, business process automation in this functional area will provide service providers with the ability to automate service creation to support use cases such as Dynamic Service Activation and Topology Automation. Service activation, reconfiguration and optimization will require accurate network and service inventory, optical reach estimation and real-time knowledge of network performance. Furthermore, as the network is deployed and additional performance statistics are available for analysis, we believe the information available can be leveraged to further optimize network design and performance as well as mitigate network performance degradations.

Service Assurance

Ultimately, the open optical network that is designed, installed, commissioned and tested must be provided to Network Operations with the tools and functionality equivalent to – or better than – those provided today. Deployment of open, multi-vendor solutions must still meet the expectations of operations staff and allow service providers to support contracted Service Level Agreements. Standard APIs accelerate the introduction of new vendors and technologies by reducing the EMS/NMS integration cycle, thereby providing cost savings. Similarly, standard APIs support a common look and feel for management of all vendors, simplifying training for operations staff.

Fujitsu's Commitment to Openness

In collaboration with key customers, Fujitsu is pioneering a transition towards open optical networking. We have continued to optimize our product portfolio and solution offering to support open, disaggregated network technologies. Some examples of our commitment to this transformation include:

- Creation of our Virtuora Network Control solution, based on open software platforms (OpenDaylight, Hadoop, etc.)
- Complete re-architecture of our optical portfolio, resulting in the creation of our 1FINITY™ disaggregated hardware platform, offering modular ROADM and transponder blades
- Industry participation in leading open optical initiatives such as Open ROADM MSA and the Telecom Infra Project (TIP)
- Support for Open APIs (Netconf/YANG/REST) on all Fujitsu developed platforms
- Creation of IT integration and consulting services focused on open networking and automation practices
- An independent Advanced Technology & Solutions Center (ATSC) for multi-vendor interoperability testing and certification

Fujitsu is collaborating with customers in redefining OSS architectures, taking advantage of exciting new technologies. Some of the benefits of this transition include unified network and service views across layers, automated network operations and real-time data analysis and action to improve CapEx and OpEx efficiency.

The Fujitsu Open Vision

Role of Open APIs and the Need for Convergence

When it comes to open standards, Open ROADM and OpenConfig data models are leading the charge. Open ROADM aims at achieving full disaggregation by defining interoperability specifications for ROADM switch, transponder, pluggable optics and a comprehensive set of Device, Network and Service models for multi-vendor SDN control. OpenConfig models for optical networks have been focused on disaggregating the transponder from the line system component. While both models are aligned with the industry definition for an Open Line System (OLS), Open ROADM models further specify the line system interfaces in order to allow for mixing of line system components. Both implementations have their advantages based on the value service providers hope to derive and the application or use case being targeted for deployment.

With the increasing interest around OLS from data center operators and service providers, we believe some of the key operational aspects that are addressed within Open ROADM will be beneficial to the industry in enabling multi-vendor interoperability – such as software download, database operations, firmware download, syslog capture and retrieval, user security functions, etc. Support for these operational aspects is missing from models such as OpenConfig, and must be addressed through vendor extensions. Alternatively, the introduction of additional OLS functions such as the bookending of non-Open ROADM transponders into the Open ROADM MSA help foster innovation. These features would allow for advanced or niche transponder modulation schemes over the Open ROADM line to allow service providers flexibility in their network deployment.

Fujitsu believes that there needs to be stronger collaboration between the Open ROADM and TIP-OOPT communities to align on the vision for OLS. We seek to leverage the work done in both these initiatives to harmonize and build consensus towards establishing a unified industry direction for open optical and development of common APIs.

ONAP: Global Automation Platform

ONAP is disrupting next-gen OSS systems by addressing the need for a common end-to-end orchestration and automation platform. Fujitsu views ONAP as an important piece for enabling Lifecycle Orchestration, and we have integrated our Virtuora Network Control solution into the ONAP environment through standard MEF APIs and REST interfaces. We believe that having an Open ROADM controller integrated into ONAP will be key to enabling end-to-end service creation over open optical networks. In enabling ONAP-based orchestration, we have exposed APIs northbound of the Virtuora Network Control solution that integrate with SDN-C, DCAE and A&AI components for Service Provisioning, Inventory, Alarms, Performance Management and Notifications. We also acknowledge that enhancements to the Master Service Orchestrator and Policy engine components will be instrumental in enabling closed-loop automation of the optical transport network infrastructure. We would like to collaborate with service providers on use cases to enable multi-layer and multi-domain operations through the ONAP platform.

Phased Evolution to Openness

Fujitsu proposes an evolutionary path to achieve the vision outlined, which leverages the flexibility and revolutionary architecture of our flagship 1FINITY hardware and Virtuora software solutions. We understand that service providers must balance near-term network goals with long-term visions that are evolving along with the industry. To this end, Fujitsu believes a phased implementation of hardware, software and APIs will help to optimally achieve service provider's goals.

In navigating the transition to an open network architecture, the Fujitsu Open Daylight-based Virtuora Network Control solution: 1) provides production-grade multivendor support and maintenance, 2) eliminates the need for proprietary NMSs/EMSs in Open ROADM configurations, and 3) provides Open APIs for integration with existing OSS/IT systems and ONAP. In addition, our modular 1FINITY ROADM platform eliminates the restrictions associated with shelf-based architectures to deliver a compact and scalable ROADM platform that is fully controlled via NETCONF/YANG, uses the same hardware components in all scenarios, natively supports alien wavelengths, and supports both Open ROADM and OpenConfig standards.

The following scenarios describe degrees of openness that may become phases of a transition plan or ends in and of themselves.

Scenario 0 – Brownfield Network Alien Wavelengths

The modular architecture and native alien support provided by the 1FINITY and Virtuora Network Control solution support alien wavelengths over third-party networks today (See Figure 2). This capability has been demonstrated to key service providers in their respective labs. In addition, Fujitsu has successfully deployed and provisioned 1FINITY transponders and muxponders over a third-party vendor's long-distance ROADM network.

With our alien wavelength capabilities, one can leverage spare capacity on existing networks for higher bit-rate services and also deploy new transponder technology in slow-growth markets, where a ROADM overbuild does not meet business case thresholds. Fujitsu provides solutions to address the path design and capacity management of alien wavelength deployments. Depending on the size and scope of deployment, an offline network reachability analysis or highly scalable, predictive machine learning approach based on the Fujitsu Conscious Network may be used. Going beyond the data plane, the open APIs available with the Virtuora Network Control solution allow straightforward northbound integration with third-party OSS systems. Southbound or East-West integration with EMS/NMS systems is also possible using standard or custom APIs.

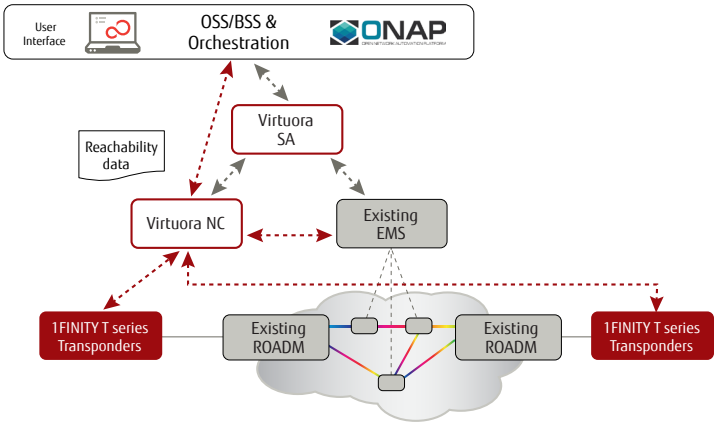


Figure 2: Brownfield Alien Architecture Summary

Scenario 1 – SDN Controlled Optical Infrastructure

This solution provides a production-ready optical network with the highest performance possible from the 1FINITY ROADMs and transponders (See Figure 3). The goal of this scenario is to allow service providers to satisfy immediate network demands with a fully operational solution from Planning and Design through Service Assurance.

This scenario allows time to establish an open, multi-vendor network architecture and evaluate production-grade solutions for the key building blocks required to satisfy operational and automation requirements.

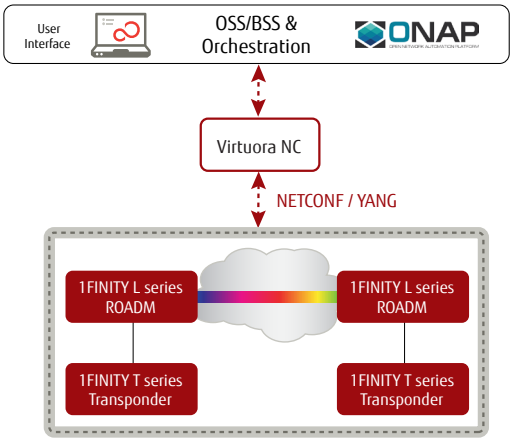


Figure 3: SDN Controlled Optical Infrastructure Architecture

Scenario 2 – Introducing Multi-vendor Open Config Transponders

Our 1FINITY platform provides a modular architecture that natively supports non-Fujitsu (Alien) Wavelengths. The equipment installed and deployed as part of Scenario 1 enables a pragmatic migration to Scenario 2. While the introduction of multi-vendor transponders is possible using proprietary vendor EMSs in an alien wavelength approach, we believe the use of Open Config best fits the use cases for multi-vendor control. To complete the scenario, our Virtuora Network Control solution will support OpenConfig service activation of third-party transponders for transmission over the 1FINITY ROADM core using Fujitsu or Open Config APIs. It should be noted that further definition of the Open Config model is necessary for ROADM line operations (See Figure 4).

To achieve production deployment and address the use case targets, collaboration on this architecture will be necessary to define:

- Workflows for service activation, design, troubleshooting and other processes
- Software tool support and responsibility for key building blocks of the control architecture
- A list of transponders for integration testing
- Scope of support for transponders (service activation, telemetry, maintenance, etc.)

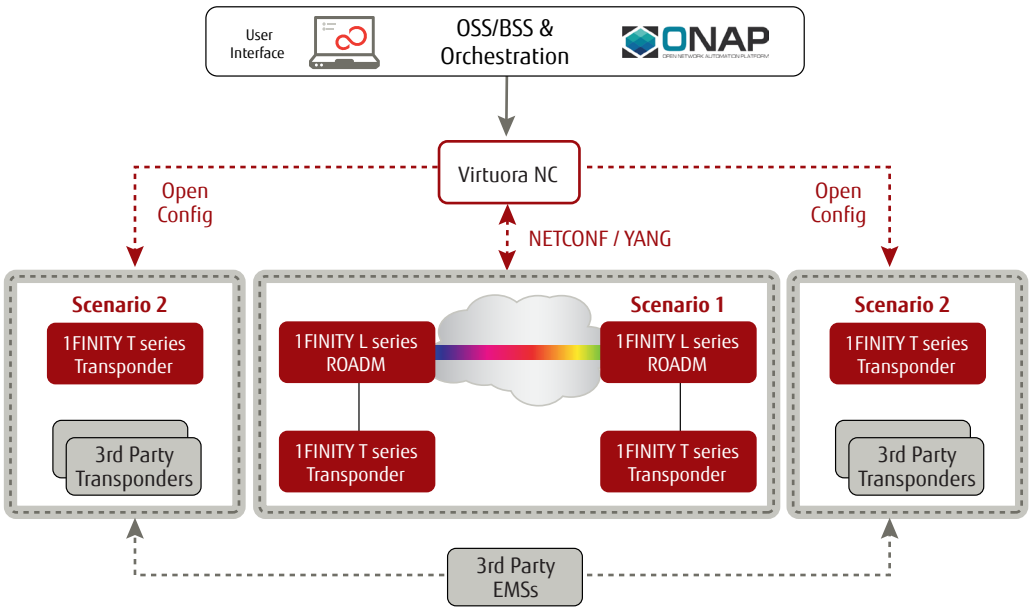


Figure 4: Multi-vendor Open Config Architecture Summary

Scenario 3 – Open ROADM Deployment

Introducing Open ROADM allows further operational simplification with the well-defined operational models and functional standardization of most optical network functions. This enables one to further minimize the IT and operational process impacts when introducing additional vendors and hardware versions into the network by adherence to common hardware modeling and behavior.

Fujitsu continues to pioneer Open ROADM, providing Open ROADM hardware and the only production-grade SDN control solution available in the market today. For applications supported by the Open ROADM specification, service providers can take advantage of the simplified management model of Open ROADM-compliant transponders and ROADM.

In Scenario 3, Open ROADM-compliant transponders and ROADM devices from any vendor are deployed for the vast majority of services under our Virtuora Network Control solution using Open ROADM YANG models. In addition, any services not defined and supported by the Open ROADM models may be deployed using transponders, managed via Open Config, across the Open ROADM line system (See Figure 5).

As production deployment for Open ROADM solutions is nascent, we welcome a collaboration on this architecture and potential management concepts for Open ROADM:

- Workflows for service activation, design, troubleshooting and other processes
- Software tool support and responsibility for building blocks of the architecture
- Management model use cases for Open Config transponders over an Open ROADM OLS
- Elimination of third-party EMSs

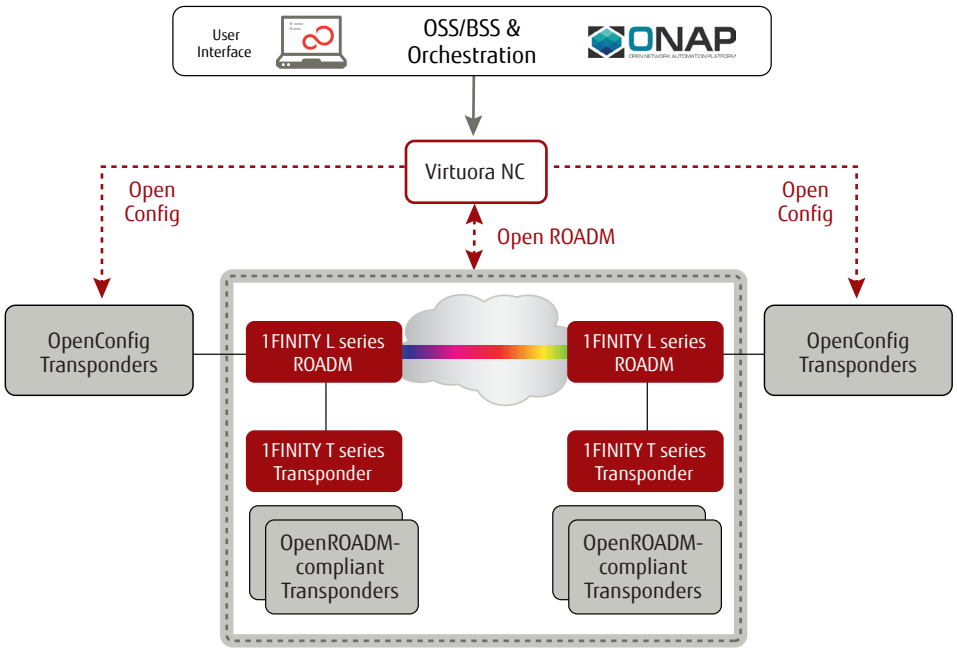


Figure 5: Fully Realized Open Optical Architecture

Addressing Automation with Conscious Networks

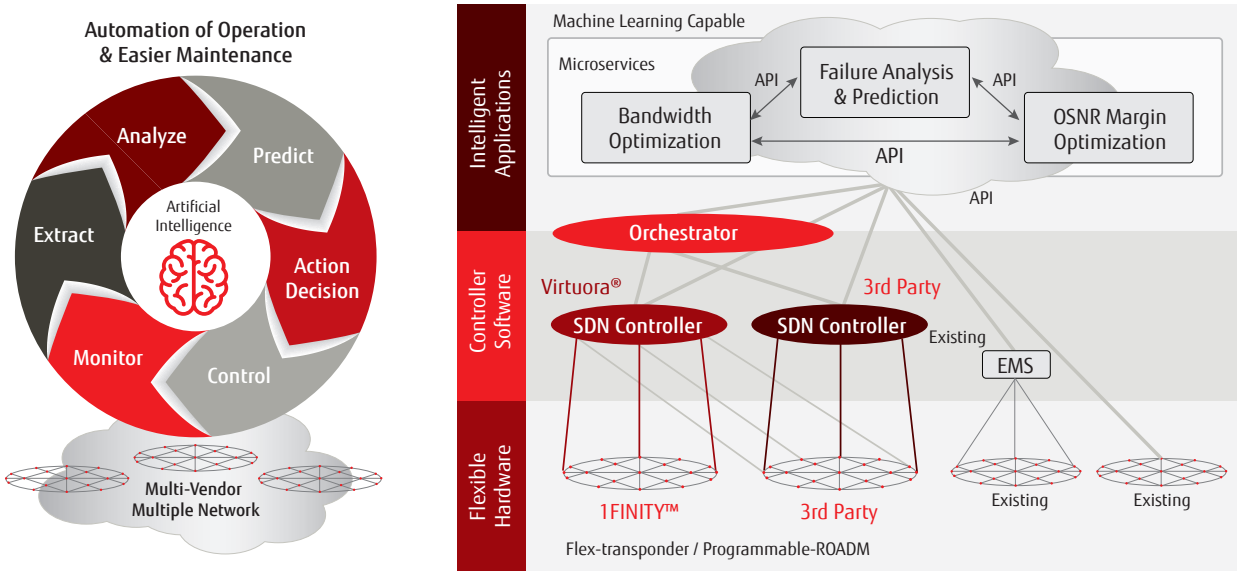
To take full advantage of the capabilities of SDN control and open access to such information as network performance data, service providers must look to intelligent networking solutions. Fujitsu is committed to providing technologies that streamline work processes and simplify operations for our customers. Our Conscious Network Intelligent Applications are microservices that can be integrated into the various layers of management/control based on one's architecture and use cases. This implementation approach enables service providers to address real network problems in the most optimal manner.

The Fujitsu Conscious Network vision offers an open architecture that supports machine-learning in a multi-vendor closed loop environment (See Figure 6). Our growing set of microservices will allow service providers to optimize open networks by integrating the best microservices and applications from Fujitsu with internal or 3rd-party applications. The initial focus of the Fujitsu Conscious Network Intelligent Applications includes bandwidth optimization to analyze wavelength utilization and recover optical spectrum, optical network margin optimization to extend reach and reduce regeneration, and optical failure analysis and prediction. We continue to develop additional use cases for Conscious Networking, and believe our capabilities in this area can be leveraged to implement on-demand, event-based, analytics-powered, control loop automation.

Summary

Open optical networks present new challenges in terms of network design, multi-vendor control, business processes and operational solutions. Fujitsu believes the migration to open networking requires the service provider to reevaluate the manner in which networks are architected, deployed and operated. As outlined above, we believe our early adoption of flexible, modular optical hardware products and software control solutions based on open source platforms give service providers a unique solution to achieve their immediate needs for new network infrastructure while facilitating migration to open networking based on unique business and technical requirements. Our innovative 1FINITY hardware platform and Virtuora Network Control solution enables service providers to evolve to open architectures based on Open Config and/or Open ROADM. This inherent flexibility allows one to deploy an optical architecture today and achieve one's open network architecture tomorrow. Furthermore, our operational expertise deploying alien wavelengths and open solutions with key carriers provides rich knowledge and support to help service providers realize the goals outlined in this white paper.

Figure 6: Fujitsu Conscious Network Closed Loop Model



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