Executive Overview
SDN Transport API Interoperability Demonstration

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The OIF is an international non-profit organization with over 100 member companies, including the world's leading carriers and vendors. Being an industry group uniting representatives of the data and optical worlds, OIF's purpose is to accelerate the deployment of interoperable, cost-effective and robust optical internetworks and their associated technologies. Optical internetworks are data networks composed of routers and data switches interconnected by optical networking elements.

With the goal of promoting worldwide compatibility of optical internetworking products, the OIF actively supports and extends the work of national and international standards bodies. Working relationships or formal liaisons have been established CFP-MSA, COBO, EA, ETSI NFV, IEEE 802.3, IETF, INCITS T11, ITU SG-15, MEF, ONF.

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“As operators move from SDN PoCs and lab trials into commercial deployments, lack of interoperability between the SDN controllers and the orchestration layer above has quickly become the biggest technical barrier for many operators. Building a standardized northbound interface and successfully testing interoperability across different vendors and different networks – as the OIF has demonstrated – is a major step forward in addressing the northbound interface challenge and bringing SDN architectures to wide-scale commercial use.”

Sterling Perrin, principal analyst, Heavy Reading.

2 Executive Summary

A sea change is underway in the telecommunications and information technology industries. The tide has gone out for legacy “hardware-defined” network architectures and the tide is rushing in for new software-defined network (SDN) architectures. Network operators around the world are planning and deploying a new wave of software-defined services to accelerate service innovation and automate network operations.

To achieve these objectives, network operators must combine hardware and software solutions from multiple suppliers across multiple network layers and then interconnect these networks with other network operators across the globe.

Demonstrating multi-layer, multi-vendor, multi-domain interoperability can only be done with real hardware and software installed in multiple carrier test facilities around the world. With that in mind, the OIF and ONF have worked together with leading carriers and network suppliers to build a global testbed to demonstrate multi-vendor SDN interoperability across multiple network layers, with ONF providing API standards and OIF managing the demo testing. Figure 1 provides an overview of the test labs, carriers and vendors involved in the demonstration.

Fig. 1: Overview of the Test Labs, Carriers and Vendors Involved in the OIF-Managed Demonstration

The goal of the testing was to verify and demonstrate the state-of-the-art for multi-layer, multi-vendor, multi-domain transport SDN, providing network operators and equipment suppliers alike a reference point for continued development.

The scope of the testing was focused on elements of the OIF Transport SDN Framework implemented by the ONF Transport Application Programming Interface (T-API) and the use case of provisioning and restoring standards-based services across a multi-vendor, multi-domain network.

Key takeaways from the demonstration include:

- T-API enables real-time network visibility and orchestration of on-demand connectivity setup, control and monitoring for multi-layer, multi-vendor, multi-carrier networks.
- T-API provides a notification interface for end-to-end services. For instance, it functions as the means for notifying applications that congestion is being observed, triggering rerouting of traffic and the addition of capacity.
- The multi-domain orchestration of services was tested using Ethernet, OTN and optical switching.
- The SDN Controller-based hub and spoke model provides efficiencies over the linear chain model for controlling network elements across multi-domain, multi-vendor network environments.

As a further note, the T-API SDK is also being leveraged by MEF in the Network Resource Modeling (NRM) and Network Resource Provisioning (NRP) projects where it is being augmented with MEF-specific extensions. Some of these APIs would be targeted in the MEF OpenCS reference implementation projects (e.g. OpenCS Optical Transport, OpenCS Packet WAN). The demonstration was also approved by ETSI-NFV as an NFV Proof of Concept demonstrating connectivity life cycle management with SDN-based network control over WAN interconnection for NFV.

3 Introduction

Carriers worldwide are planning and deploying software-defined transport networks with goals of accelerating multi-layer service provisioning and delivering dynamic, on-demand transport services for cloud-based applications. Defining, testing and assuring the interoperability of key network functions and interfaces can accelerate new service delivery while automating network operations. Widespread adoption of SDN depends on the availability of standardized APIs not specific to any vendor or underlying technology. To that end, the OIF defines the Transport SDN Framework that identifies these key functions and application programming interfaces (APIs) for transport networks.

This paper summarizes the results of the 2016 OIF SDN Transport API Interoperability Demonstration, in which the OIF and ONF partnered with global carriers and leading equipment suppliers to test key elements of SDN Transport APIs (T-API). The OIF-managed demonstration, which was conducted over six weeks in late 2016, addressed multi-layer, multi-vendor, multi-domain service deployment and restoration.

T-API is designed to be the interface between controllers at different levels of an SDN controller hierarchy. In a typical deployment, T-API would be the interface between the Domain Controllers for several network domains and a higher level Multi-Domain Controller that acts as a parent, as shown in Figure 2. As such, T-API plays a critical role in enabling this connectivity across the hierarchy.

By abstracting the details of the lower level Domain, T-API supports the integration of Domains of different technology and different vendor equipment into a single, virtualized network infrastructure:

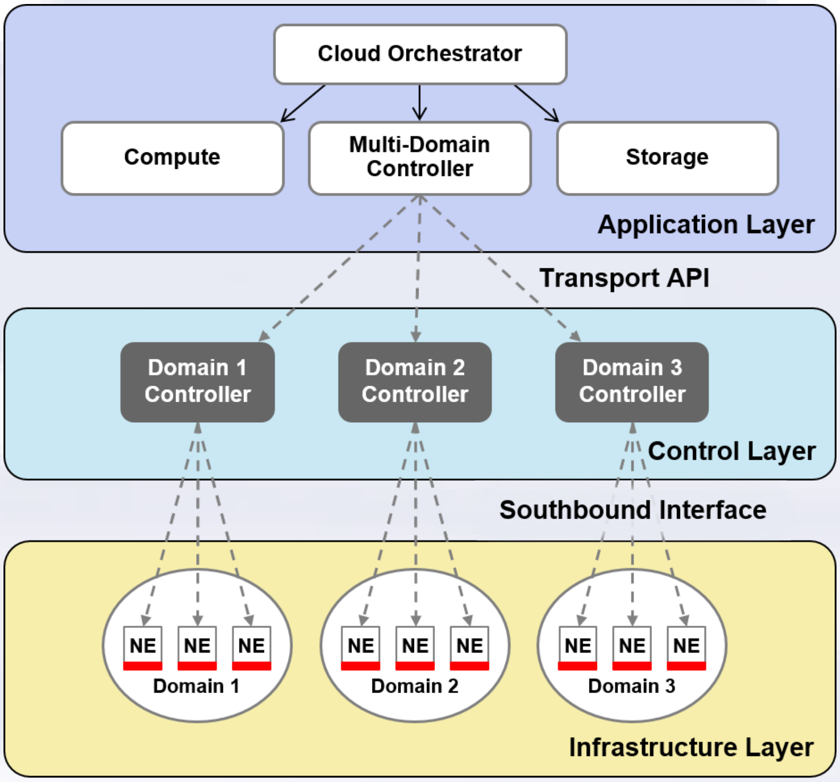

Fig. 2: API Multi-Domain, Multi-Vendor Integration

T-API is a product of the ONF Open Transport Working Group (OTWG) with input from the OIF and joint interoperability testing. T-API is closely based on the ONF's Common Information Model [CIM]. The CIM effort has been adopted by organizations like TMF, ITU-T, OIF and MEF as the basis for definition work, T-API also incorporates work from multiple ONF Open Source SDN (OSSDN) projects.

The primary objective of T-API is to enable full network programmability across domains without requiring full interoperability between each network element. Provisioning end-to-end optical service in virtualized networks requires a common abstraction model. This is achieved by using T-API as a North-Bound Interface (NBI) for domain controllers.

4 Scope of Testing

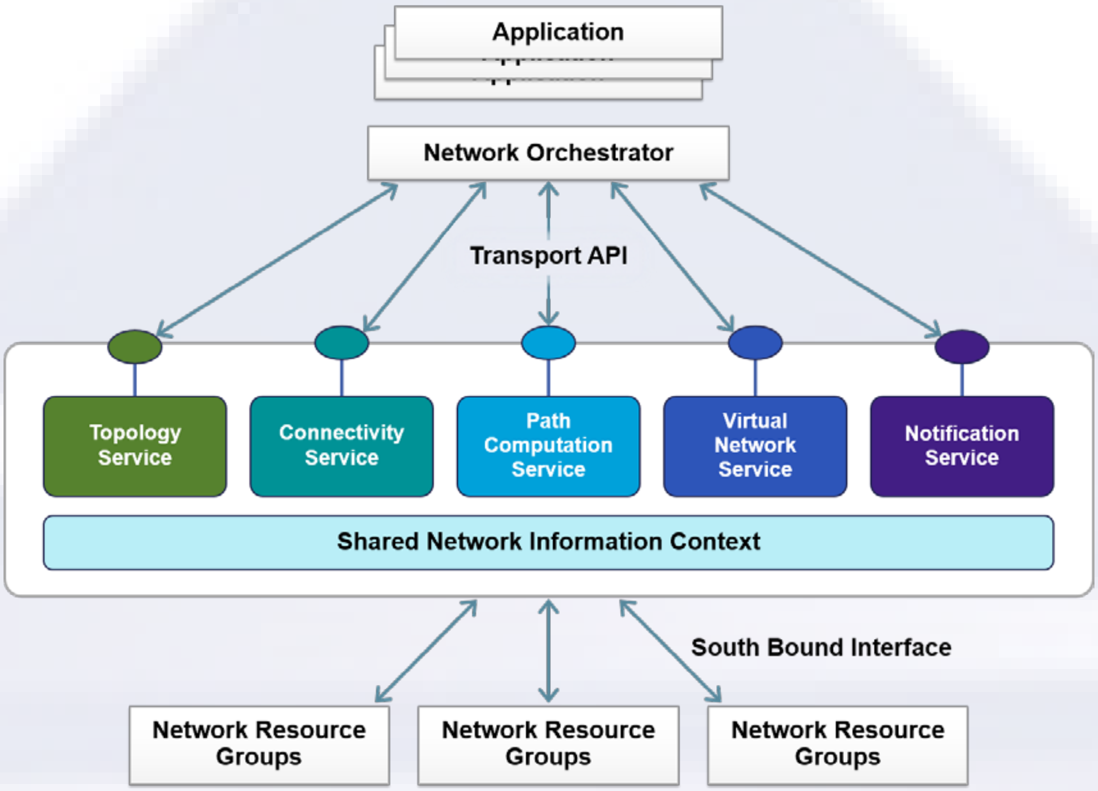

Fig. 3: Top Level Decomposition of the T-API Services [1]

The demonstration included both intra-lab testing and subsequent inter-lab testing between the host carriers. During the intra-lab phase, testing was conducted between Multi-Domain Controller implementations, including verification of data plane connectivity after setup of a connectivity service. Several use cases were tested as discussed below.

During the inter-lab phase, testing was conducted between Multi-Domain Controllers and Domain Controllers in different carrier labs.

4.1 Topology Service API

Topology Service API clients may retrieve basic data about controlled networks – an abstract view of devices and the way they interconnect. This data includes important network inventory information, establishing a foundation for other parts of T-API including Path Computation Service, Connectivity Service and Virtual Network Service. The Topology Service API retrieves details of Node

objects and NodeEdgePoints contained in the specific Topology and Node. This information can be used for diverse path calculation and rerouting during failure. Topology Service API also provides data for more sophisticated applications, such as deeper optimization of resources involving more than just a one-time path computation. This opens new possibilities for more advanced services.

4.2 Connectivity Service API

The Connectivity Service API supports operations related to the lifecycle of a connectivity service between two or more endpoints at the edge of a transport network. Connectivity Service API clients can also retrieve information about connectivity services.

For the demonstration, Ethernet point-to-point private line services were tested as the primary use case. The Ethernet service was transported over packet, OTN ODU or OTN OCh switched networks depending on the particular vendor and domain.

4.3 Notification Service API

The Notification Service API allows the client to subscribe to notification of events. It establishes a connection to allow communication of updates such as state changes. It should be noted that other APIs are client-initiated. The Notification Service API allows you to choose what notices you want to subscribe to across the different APIs/Services. These very specific notifications enable software systems to take appropriate responses.

4.4 Multi-Domain Service Provisioning

The Multi-Domain Connectivity Service was one of the main use cases tested by the demonstration. The testing included the local and end-to-end path constraints as well as local and end-to-end recovery.

During the testing, a number of steps were executed by a Multi-Domain Controller in working with multiple lower level optical Domain Controllers as shown in the following figure:

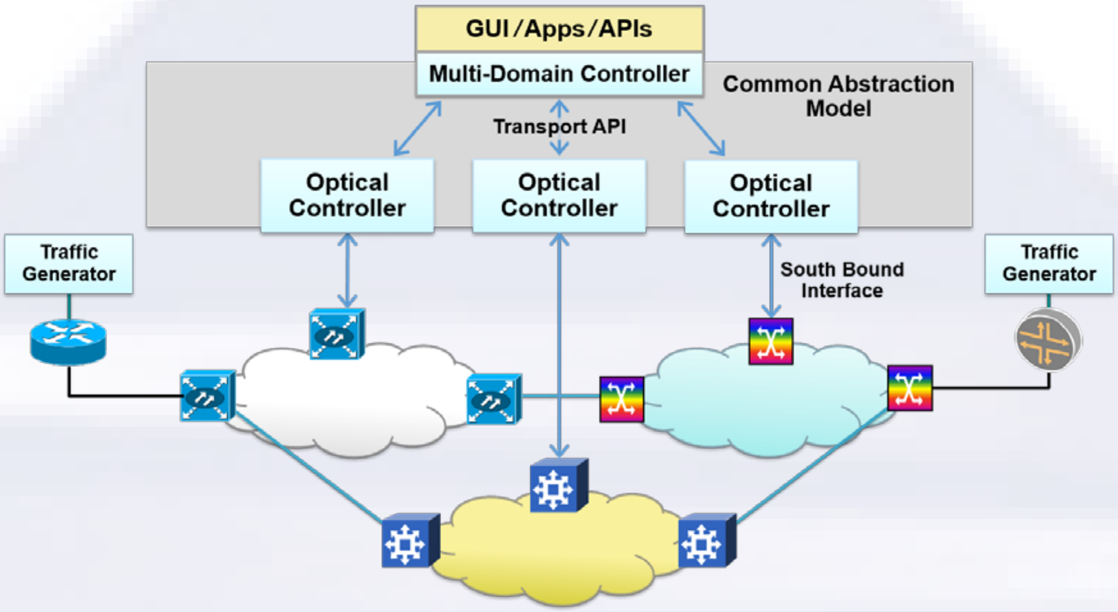

Fig. 4: Multi-Domain Topology for Connectivity Service Use Case

The initial stage of testing involved the Multi-Domain Controller querying its Domain Controllers for their topology information using the Topology API. The Multi-Domain Controller then built a multi-domain topology that was then used to compute paths for new services.

In the next stage of the Use Case test, the Multi-Domain Controller built a multi-domain connectivity service using the Connectivity Service API to create the required services in each domain. Specifically, the Multi-Domain Controller issued a Connectivity Service Request to the optical domain controllers to establish connectivity through the L0 networks.

In subsequent states of the Use Case, the Multi-Domain Controller built multi-domain connectivity services using various local and end-to-end path constraints, including requirements for diverse routing and using specified links. Finally, local and end-to-end recovery was specified in the Use Case, including local and end-to-end service recovery.

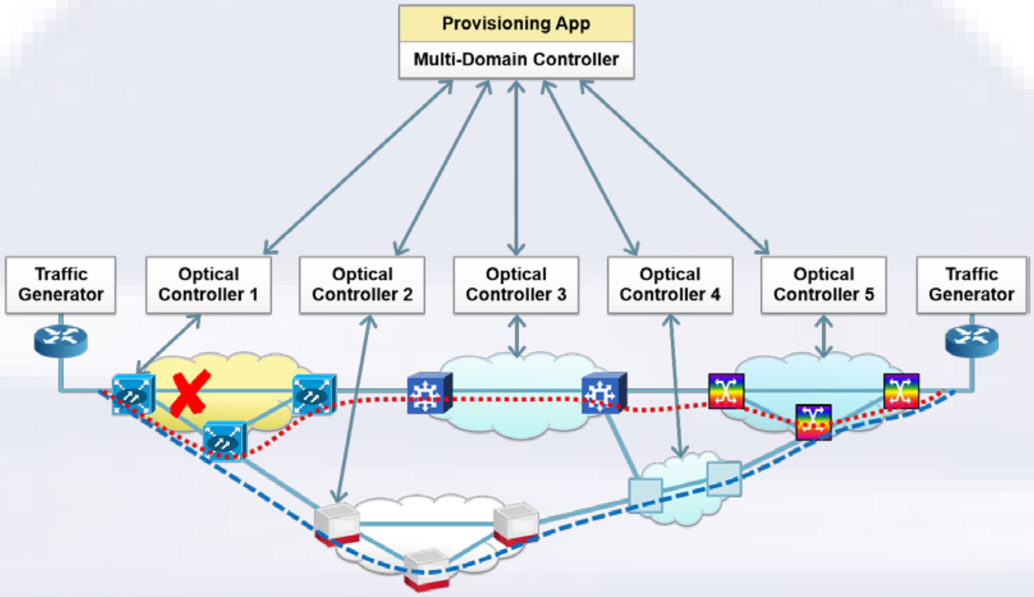

Fig. 5: Local and End-to-End Recovery

5 Key Takeaways

The 2016 SDN T-API Interoperability demonstration was successful and served to document the state-of-the art for transport SDN implementations. Several key takeaways resulted from the testing:

1) T-API Benefits

SDN allows the rapid development of new service offerings by enabling programmatic control of transport networks and equipment. SDN requires open, well defined T-APIs, paving the way for carriers to develop multi-vendor, multi-layer, multi-domain service delivery systems that accelerate service deployment and automate operations.

Furthermore, resiliency and resource utilization of the network can be improved through coordinated multi-layer optimization techniques implemented through a centralized network control function that includes a view of both packet and optical layer topologies and the ability to optimize resource utilization globally.

T-API can be used for real-time orchestration of on-demand connectivity set-up, control and monitoring across multi-layer, multi-vendor and multi-carrier networks. These capabilities will have many applications, including secure enterprise connectivity to public cloud resources, connectivity for 5G infrastructure, dynamic network services, etc..

2) The application of web-based tools and technologies to the development of new protocols is accelerating the pace of development. T-API builds on the foundation of open software and open systems guided by the ONF, the OIF, MEF and other organizations. The open design enables multi-vendor controller architectures to interoperate. Each of the carrier labs hosting this demonstration was able to test vendor interoperability across multiple layers of the network.

3) The SDN Controller-based hub and spoke model provides efficiencies over the linear chain model for controlling network elements across multi-domain, multi-vendor network environments. The demonstration showcased how the end-to-end solution could scale using recursive hierarchical controller architecture, interfacing with the same set of transport APIs and abstraction concepts at every level of controller hierarchy.

4) Automated provisioning of standardized services across multiple network layers requires a rich suite of open software interfaces, many of which exist today in commercially available solutions, although vendor implementations are not yet fully interoperable out of the box. The process of onboarding these new services requires extensive testing. Plugfests and interoperability demonstrations, such as this event, provide a valuable forum for carriers to assess the state of the market. These interoperability demos also provide a valuable channel for vendors to hear directly from carriers about their requirements for interworking.

5) The MEF has stated its interest in leveraging the T-API SDK for its Network Resource Modeling (NRM) and Network Resource Provisioning (NRP) projects, where it is being augmented with MEF-specific extensions. Some of these APIs would be targeted in the MEF OpenCS reference implementation projects (e.g. OpenCS Optical Transport, OpenCS Packet WAN).

6 Appendix A: List of Contributors

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7 Appendix B: About the OIF

The OIF facilitates the development and deployment of interoperable networking solutions and services. Members collaborate to drive Implementation Agreements (IAs) and interoperability demonstrations to accelerate and maximize market adoption of advanced internetworking technologies. OIF work applies to optical and electrical interconnects, optical component and network processing technologies, and to network control and operations including software defined networks and network function virtualization. The OIF actively supports and extends the work of national and international standards bodies. Launched in 1998, the OIF is the only industry group uniting representatives from across the spectrum of networking, including many of the world's leading service providers, system vendors, component manufacturers, software and testing vendors. Information on the OIF can be found at http://www.oiforum.com.

8 Appendix C: About the ONF

Launched in 2011 by Deutsche Telekom, Facebook, Google, Microsoft, Verizon, and Yahoo!, the Open Networking Foundation (ONF) is a growing nonprofit organization with more than 140 members whose mission is to accelerate the adoption of open SDN. ONF promotes open SDN and OpenFlow technologies and standards while fostering a vibrant market of products, services, applications, customers, and users. For further details visit the ONF website at: http://www.opennetworking.org.

9 Appendix D: Glossary

API	Application Programming Interface
CIM	Common Information Model
ETSI	European Telecommunications Standards Institute
IA	Implementation Agreement
ITU-T	Telecommunication Standardization Sector of the International Telecommunications Union
JSON	JavaScript Object Notation
MEF	Metro Ethernet Forum
MD	Multi-Domain
NFV	Network Functions Virtualization
NBI	Northbound Interface
OCh	Optical Channel
ODU	Optical channel Data Unit
OF	OpenFlow
OIF	Optical Internetworking Forum
ONF	Open Networking Foundation
OpEx	Operational Expenditure
OSSDN	Open Source SDN
OTN	Optical Transport Networking
OTU	Optical channel Transport Unit
PoC	Proof of Concept
SDK	Software Development Kit