Optical Network Programmability – Requirements and Applications

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Abstract—Datacenter operators and internet content providers require optical network programmability to efficiently interconnect distributed datacenters. This paper describes the requirements, applications and use cases for optical network programmability. Based on application scenarios, open northbound APIs with different levels of control and abstraction to address different network operator requirements which are defined. For their illustration, use cases for optical network programmability show current research directions.

Keywords—component; formatting; style; styling; insert (key words)

I. INTRODUCTION

In addition to mobile services, cloud services are becoming a main traffic growth factor, and distributed mega datacenters are increasingly requiring flexible optical networks with on-demand self-service for their interconnection [1][2]. Hence, a more programmatic mode of operation and simpler integration into existing datacenter control frameworks is needed. Software-Defined Networking (SDN) is a promising approach to address such programmability. The basic idea of SDN is to separate the control plane from the forwarding plane. The control of multiple forwarding devices is handed over to a logically centralized entity — the SDN controller. This supervisory role gives the controller a holistic view of the network which is an integral requirement for making the network as a whole programmable and allowing for better overall forwarding decisions. By exposing an application programming interface (API), network elements are no longer closed and vendor dependent, but become rather open and programmable. For transport SDN, the control protocol is turning from OpenFlow, which was primarily designed for connection-less, packet-switched L2 and L3 networks, to model-driven APIs based on YANG [3] models. This approach has the advantage that different APIs, like Command-Line Interface (CLI), REST, NETCONF [4], or RESTCONF [5], can be programatically generated directly from the YANG model. A system vendor can open its proprietary YANG models or additionally support generic, vendor-independent models. The model-driven approach allows to be consistent with different models for different applications & abstraction levels.

In this paper we first define requirements for programmable optical networks, then we describe different network application scenarios, and finally we present ongoing research projects and current results aiming to solve the technical challenges of programmable optical networks.

II. REQUIREMENTS

In this section a number of key requirements for programmable networks are discussed.

The first requirement is Ease of Use. Datacenters use state-of-the-art operation systems. Server loads are monitored and optimized, with loads continually being balanced across all available resources within their walls. Traditional network management software is not compatible with datacenter software, thus preventing the latter from truly optimizing end-to-end multilayer packet flows between interconnected datacenters. The network should support a simple programming interface for the automation of repetitive actions based on templates.

Openness is an important requirement to avoid hard vendor lock-in. Openness can be achieved at multiple levels. First of all, the network should support multiple SDN controllers, ideally open-source controllers like OpenDaylight. Secondly, by using a model-driven approach, a datacenter operator can use the model and the procedure calls defined in the model to integrate the network into their own operation systems.

Programmability of the network is required to support application-driven automation of operational procedures rather than manual configuration and management. To support programmability, application programming interfaces can be generated from the YANG models. The models include service templates and remote procedure calls e.g. for topology dissemination, path calculation, and service provisioning.

Finally, abstraction is required for applications like multilayer interworking, multi-vendor interoperability, or network virtualization (delegation of control of a virtual slice of the network to a client).

III. APPLICATIONS FOR PROGRAMMABLE OPTICAL NETWORKS

The level of control and abstraction required for Data Center Interconnect (DCI) customers varies widely. Fig. 1 shows different application scenarios for programmable optical networks for datacenter interconnect.
A. Direct APIs to NEs for Simple Connectivity

For simple connectivity of point-to-point networks, as shown on the left side of Fig. 1, often direct APIs are the right choice. In this case, network elements are provisioned using Command Line Interfaces (CLI), sometimes with scripting routines. Basic Representational State Transfer (REST) interfaces can be used here, as well. The model is typically a vendor-specific or generic network element API, as in these simple application scenarios a low level of abstraction is required.

B. Network-level APIs for Meshed Networks

For more complex networks beyond simple point-to-point links, e.g. metro/regional infrastructure networks as shown in the middle part of Fig. 1, APIs with network-level programmability are required. The aforementioned RESTful interface is one example. Another option for the communication with the network elements is the Network Configuration Protocol (NETCONF). NETCONF uses YANG models to represent the configuration and is already popular with routers and switches. RESTCONF attempts to combine the advantages of both REST and NETCONF, by using a RESTful interface running over HTTP for accessing data defined by a YANG mode and stored in a NETCONF data store. These interfaces are provided by a centralized network intelligence.

C. Network Hypervisor for Abstraction, Virtualization and Multitenancy

Finally, for more complex applications like multidomain orchestration, or IP over DWDM multilayer interworking, a higher level of abstraction is required. Additionally, virtualization and multitenancy are required if control over a virtual slice of the network should be delegated to a client. A network hypervisor, which acts as an abstraction and virtualization layer as shown in the right part of Fig. 1, supplements the centralized intelligence.
The SDN network orchestrator is communicating with the different domains via the Control Orchestration Protocol (COP). COP has been defined using the YANG modeling language and can be transported using REST or RESTCONF. STRAUSS has open sourced the COP yang models and tools to support COP’s adoption in the academic as well as the industry community [7]. COP includes following models:

- Call
- Topology
- Path Computation

### B. Multilayer interworking (ACINO)

ACINO [8] is focusing more on the communication between the application and the orchestrator – including the underlying network controllers. Following an application-centric approach to transport networks it is expected that application requirements can be fulfilled more accurately by propagating individual requirements to the transport layer. Therefore, the offered service is tailored to the application’s needs.

The general idea is to create an orchestrator which exposes a set of high-level primitives to the applications interfacing northbound. Through this interface the application can express its intent and receive the needed service. The application’s requirements are translated into commands that are directed toward the IP and optical controllers respectively. This utilizes multilayer planning and configuration capabilities of the orchestrator.

V. CONCLUSION

Transport SDN brings programmability & virtualization to optical networks. A programmable optical networking is key to future-proof packet-optical integration and must offer open application programming interfaces, ideally using YANG model-driven approach, to support operation and management systems of network operators as well as open-source SDN controllers. Different levels of control and abstraction allow network programmability from box-level APIs for simple point-to-point connectivity, to network-level APIs for network level services, and finally to abstract APIs for multi-vendor interoperability, multi-domain orchestration, and multilayer interworking.

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