Using YANG for the Dissemination of the Traffic Engineering Database within Software Defined Elastic Optical Networks

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***Abstract*—This paper presents the challenges and purpose of building the Traffic Engineering Database (TED) to facilitate Software Defined control of an Elastic Optical Network (EON). It explains how a standardized protocol and data model can facilitate this and describes a YANG model that has been developed to represent the TED including the representation of nodes, transponders, links, and available media channels available. This model also represents the established connections (Label Switched Paths – LSPs) between endpoints.**

***Keywords*—component; Networks, assignment and routing algorithms, network topology, optical**

I. INTRODUCTION

Transport networks are rapidly evolving from current static and inflexible Dense Wavelength Division Multiplexing (DWDM) systems towards software-defined Elastic Optical Networks (EON), using flexi-grid transmission schemes and dynamic switching technologies [1]. This approach aims at to utilize technology to increase both the scalability and agility of the transport network, allowing resource optimization and scaling of bandwidth as demands change and increase. In parallel, there is a need to develop innovative network management mechanisms to reduce deployment and operational complexity, and maximize benefits of flexi-grid capabilities. This has led to leveraging emerging Software Defined Networking (SDN) techniques to plan, control, and manage the transport network resources centrally and dynamically.

To operate an EON, its capabilities, connectivity, and current operational state needs to be described and disseminated. Specifically, in an SDN approach to the operation of an EON, this information has to be collected from the network and exported to the "controller" that has responsibility for selecting which network resources will be used to support services and connectivity across the network, This information includes data about nodes, transponders, links, the media channels available that provide the connectivity graph within the network, and those operational and usage stage of these components. This data-set is collectively known as the Traffic Engineering Database (TED).

NETCONF [2] is a protocol defined by the Internet Engineering Task Force (IETF) to facilitate the configuration of network devices. YANG [3] is the data modeling language normally used to encode information passed by NETCONF. This paper describes a YANG data model that has been developed to provide a holistic view of an EON, and to enable dissemination of the TED for the network in order to achieve SDN control of the network by a centralized control systems or an Operational Support Systems (OSS).

The model has been developed to represent two different optical technologies: Wavelength Switch Optical Networks (WSON) and flexi-grid. It also allows the representation of the optical layer of a network, combined with the underlying physical layer. This model is a key component for exporting network state to the Topology Server within an Application-Based Network Operations (ABNO) [4] platform, or with any other controller, for on-demand provisioning or optimization of optical paths. This technology may be seen as key component for any SDN-based approach to deploying and operating optical networks [5].

An additional benefit of a common data model described in a well-known modeling language is that representations of networks can be shared and snap-shots of the network state can be archived. This is useful for research into networking techniques and methodologies, for network diagnostics, and for sharing information about deployed or theoretical networks.

This paper discussed the key requirements to build and disseminate the TED, facilitating software defined control of an elastic optical network. We summarises the development of a suitable data model and dissemination mechanism. This model is described in detail and the application results are presented. Finally, we summarise the current state of Standardisation.

II. Dissemination of Optical Network Information

A. *Using the Traffic Engineering Database in a Software Defined Optical Network*

The Traffic Engineering Database is a full set of information that describes a single network layer, multiple network domains, or even an inter-layer or inter-domain network. Fundamental to its value is that it should correctly reflect the network topology and its state at a specific moment in time. For archival purposes this will be a snap-shot at a recorded time, but for operational purposes it needs to be accurate at the time operational decisions are made which means it has to be updated to reflect changes in the network.

The TED may be maintained by a Topology Server. This is a logical or abstract functional component within the network architecture. It is responsible for gathering the information from the control plane, direct from the data plane, from Operations, Administration, and Maintenance (OAM) functions, and from other management components such as inventory management systems and network audit tools. The Topology Server exports the TED to other architectural components that use the information to enable features and services over the network. For example:

- The Path Computation Element (PCE) [6] performs path computation to select optimal and functional paths through the optical network. It requires detailed information from the optical layer to consider the physical impairments. Moreover, a stateful PCE [7] requires knowledge of the established connections in the network to carry out optimization. The PCE can collect such information from the Topology Server, to ensure network views are synchronized.

- A Virtual Network Topology Manager (VNTM) is in charge of managing the Virtual Network Topology (VNT) [8] in multi-layer scenarios. The maintenance of virtual topologies is complex, and the VNTM has to decide which nodes are to be interconnected in the lower-layer in order to fulfil the resource requirement of the upper-layer. This requires the instantiation of connections in the optical layer to cope with all of the demands of the upper layer, whilst minimizing resources in the underlying network. When this capacity is no longer required, the VNTM has to release unwanted resources in the lower-layer network ready for future uses. The VNTM must have current and detailed information from the Topology Server to make optimal decisions and maximize network resource efficiency.

- The concept of SDN is growing in popularity [9]. In this context an SDN Controller is an application that converts user requests into provisioning instructions for the network. However, an SDN controller for an optical network must also be aware of existing physical layer capabilities and availability. A clear representation of the topological information facilitates operation of the controller itself, and the interoperability between controllers for multi-domain and multi-technology applications.

III. Mechanisms for Disseminating Network Topology Information

As described previously, there are various applications that require access to a TED in order to perform their functions. A Topology Server that is responsible for storing and providing network topology information can be present on a device in the network, or can be a distinct server, however, regardless of implementation, there is a need for the Topology Server to export the information that it collates for use by the other applications.

A number of mechanisms have been proposed to serve this purpose, but it should be clear that a standardized approach is necessary so that different applications can all interact with a Topology Server and so that different Topology Servers can be implemented.

- The PCE Protocol (PCEP) is used by applications to request path computations to be performed by a PCE and for the PCE to return its responses. From that perspective, the protocol is closely associated to one of the consumers of the TED (specifically the PCE) and it has been suggested that PCEP might be used as the export protocol [10]. However, PCEP was not designed with this purpose in mind, and other components that are not themselves PCEs would need to implement a whole protocol purely to achieve this element of the functionality.

- BGP Link-State (BGP-LS) [11] is a set of extensions to the Border Gateway Protocol (BGP) designed to allow a BGP speaker in a network to export the TED information to which it has access. Both the receiver of information and the sender must implement BGP which may not be a significant issue in many packet networks, but this could be an unsuitable solution for an optical network where network nodes will not typically implement BGP.

- Netconf [2] and YANG [3] are the IETF's standardized configuration protocol and configuration modeling language. In practice, a configuration protocol is also used to read status information from configurable devices and even to convey asynchronous notifications. Since there is a move to standardize the configuration of all network devices using Netconf and YANG, it makes perfect sense to propose the use of this protocol and its modeling language to export the TED from a Topology Server. All that is required to enable this is an agreed and standardized YANG model with which to represent the TED.

IV. Proposed Optical Network Data Model

Several YANG models have already been specified for network representation. For instance, the work in [12] has proposed a YANG model of a TED, but only covering the IP layer. A YANG model has also been proposed in [13] to configure optical DWDM parameters. In addition, a TED has been proposed for optical networks in [14], but this approach did not specify a YANG model to enable configuration of elements.

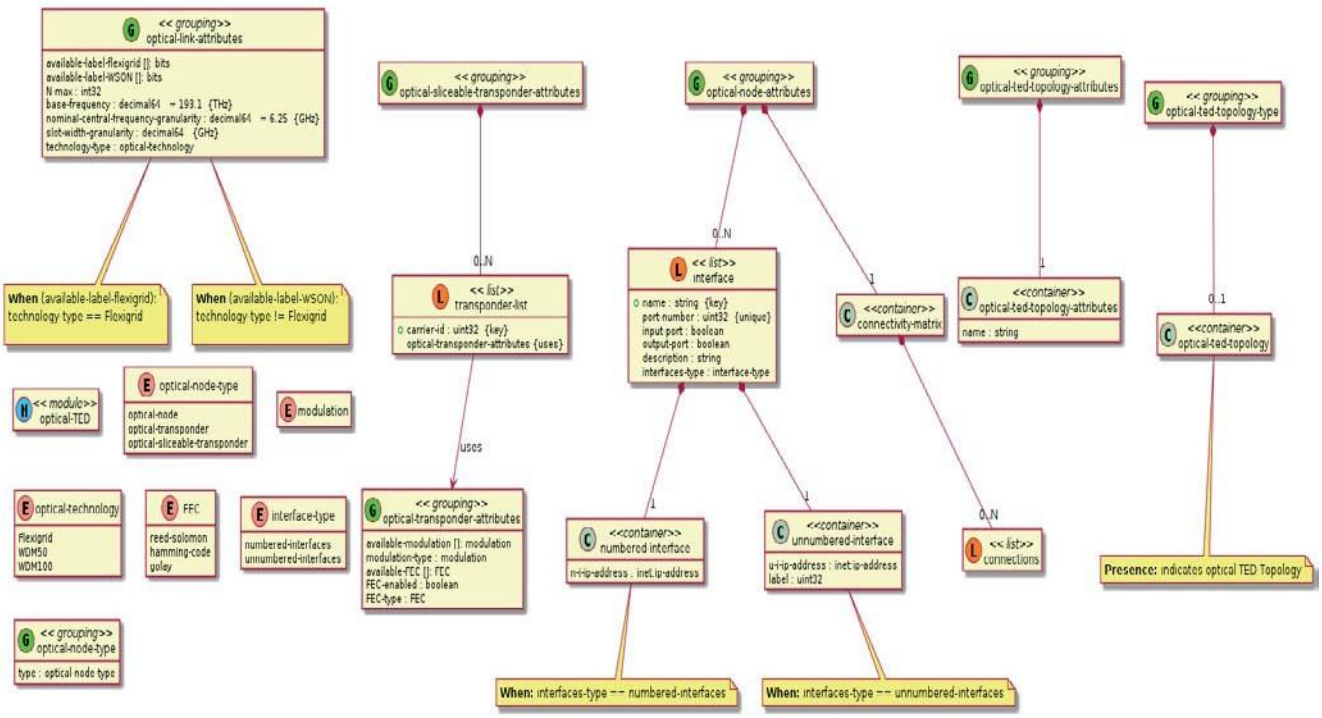

Figure 1: Simplified view of the optical TED YANG module class diagram.

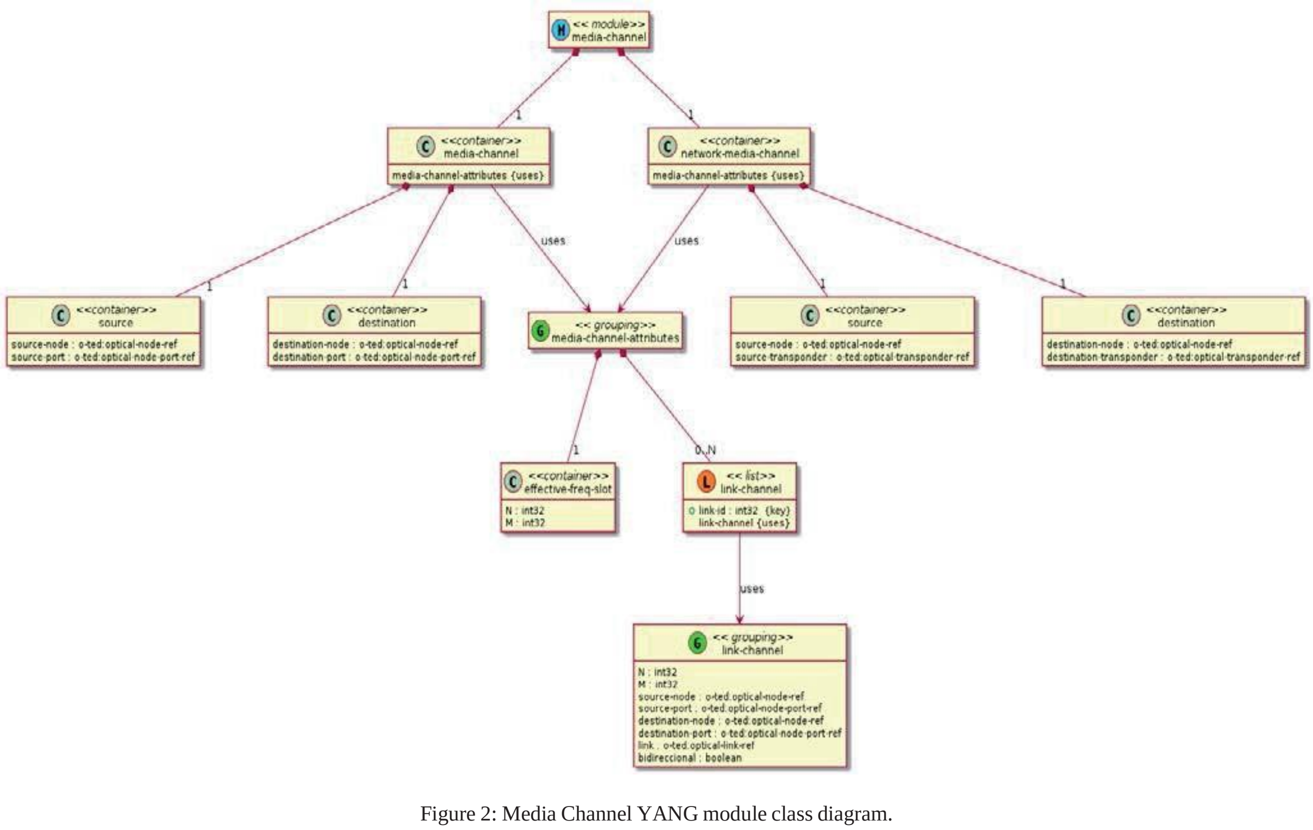

Figure 2: Media Channel YANG module class diagram.

The YANG model we propose is spilt into two modules: Optical TED and Media Channel. These are represented in Figure 1 (Optical TED) and Figure 2 (Media Channel) describe the class diagrams and dependencies within each module.

A. *Optical TED YANG Module*

In order to be compatible with existing proposals, we augment the definitions contained in [15], by defining the three main components, optical-node, optical-transponder and optical-link; optical-sliceable-transponders are also defined. Each element is defined as a container and includes a set of attributes. The module also includes the data types for the type of modulation, the optical technology such as Forward Error Correction (FEC).

B. *Media Channel YANG Module*

The model defines two types of media channel, a Media-Channel which represents a (effective) frequency slot supported by a concatenation of media elements (fibers, amplifiers, filters, switching matrices.). The second, is Network Media Channel: is a media channel that transports an Optical Tributary Signal. In the model, the network media channel utilises end-points transponders, which are the source and destination of the optical signal.

V. APPLICATION OF THE MODEL

This section provides an example of the how the model introduced in the previous section may be used. Figure 3 (Topology Example) demonstrates a simple topology, where two physical paths interconnect two optical nodes with transponders. To describe the media channels that interconnect transponders A and E, first of all we have to populate the optical TED model with all elements in the network.

1. We define the transponders *A* and *E*, including their FEC type (if enabled), modulation type, and sliceable capability (again, if enabled). We also provide node identifiers and addresses for the transponders, as well as interfaces included in the transponders.

2. This is repeated for nodes *B*, *C*, and *D*, providing their identifiers, addresses and interfaces, as well as the internal connectivity matrix between interfaces.

3. Then, links *1* to *5* that interconnect the nodes and transponders are defined, indicating which labels are available, both in flexi-grid or WSON. Other information, such as the slot frequency and granularity are also provided. Next, we can specify the media channels from the information we have included in the TED. Note that every element in the TED has a reference, and this is the way in which they are called in the media channel.

4. Depending on the case, it is possible to define either the source and destination node ports, or the source and destination node and transponder. For instance, for the path *x* we would specify a network media channel, with source transponder *A* and source node *B*, and destination transponder *E* and destination node *C*.

5. Then, for each link in the path x, we indicate which channel we are going to use, providing information about the slots, and what nodes are connected.

Finally, the optical TED has to be updated with each element usage status each time a media channel is created or torn down.

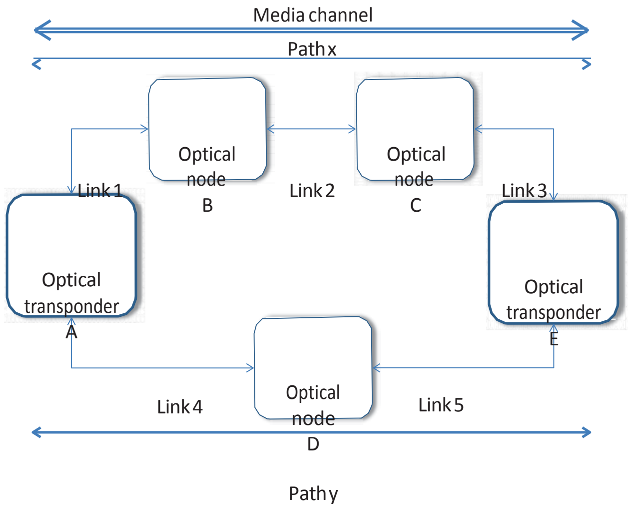

Figure 3: Topology Example.

VI. IMPACT ON STANDARDIZATION

A key output of YANG model development effort for EONs has been a contribution to the IETF, in the form of an Internet-Draft within the “Common Control and Measurement Plane” (CCAMP) working group “A YANG data model for WSON and Flexi-Grid Optical Networks” [16]. The CCAMP working group is responsible for standardizing a common control plane and a separate common measurement plane for technologies found in the Internet.

Most recently (December, 2014) the IETF created a new working group entitled “Traffic Engineering Architecture and Signaling” (TEAS). This new working group is responsible for defining MPLS and GMPLS traffic engineering architecture, standardizing the signaling protocol, and identifying required related control-protocol functions, i.e., routing and path computation element functions and developing YANG models for network topologies and technology specific network attributes.

Our objective will be to progress the YANG model defined and discussed in this paper within the new TEAS working group, and eventually publish our proposal as the IETF Internet RFC Standard YANG model to model flexi-grid and WSON nodes, transponders, links, and available media channels.

VII. CONCLUSIONS

The paper has presented the motivation for a YANG model for the configuration of elastic optical networks and WSON, enabling SDN-based applications for on-demand provisioning and optimization and flexible control of optical resources. We have introduced the YANG model that can be used to represent the TED of an optical network. We continue to develop this work in the IDEALIST project through experimental implementations in our next generation optical network testbed to validate its feasibility within the ABNO architecture and other applications.

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