Demonstration of Open and Disaggregated ROADM Networks Based on Augmented OpenConfig Data Model and Node Controller

Liang Dou[1], Lei Wang[1], Sai Chen[2], Jingchi Cheng[2], Zhao Sun[1], Ming Xia[3], Huan Zhang[2], Li Xiao[4], Jian Xu[4], Jiekui Yu[4], Chongjin Xie[3]

[1]*Alibaba Cloud, Alibaba Group, Radiance JinHui Tower, Chaoyang District, Beijing, China,* [2]*Alibaba Cloud, Alibaba Group, Hangzhou, China,* [3]*Alibaba Cloud, Alibaba Group, Sunnyvale, USA,* [4]*Accelink Technologies Co. Ltd, Wuhan, China*

douliang.dl@alibaba-inc.com

Abstract: By augmenting OpenConfig data model of *optical-wavelength-router*, we demonstrate a ROADM network with disaggregated devices. Node level controller is implemented in our network management system with various operations on both degrees and media channels.

1. Overview

Open and disaggregated optical transport systems have been deployed in inter-data center interconnect (DCI) networks [1]. DCI networks for mega data centers are typically point-to-point networks as the number of data centers is small. However, in metropolitan areas with many small data centers, it is beneficial for a DCI network to use a mesh architecture. Reconfigurable optical add-drop multiplexers (ROADMs) enable programmable optical channel route and reconfigurable network architecture in a mesh DCI network. It can not only reduce the number of fiber links, but also significantly increase the network flexibility and efficiency as well [2].

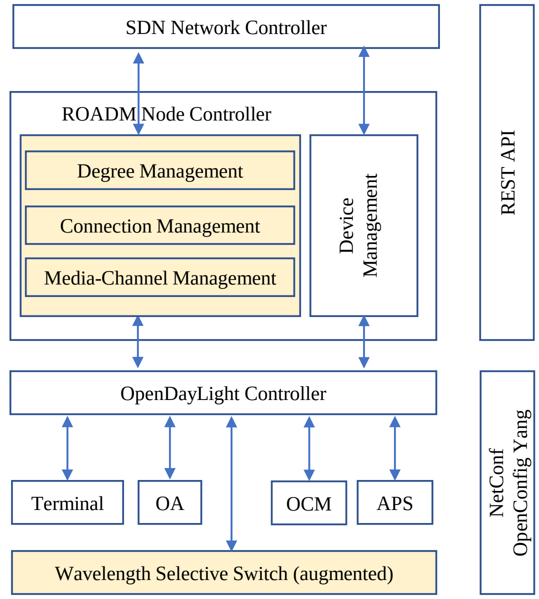
For a disaggregated network, various devices from different vendors follow the same open and standard interface so that they can interoperate and be managed by a unified control and management platform [3]. OpenConfig provides data models to describe devices behaviors, including system, terminal and optical line devices [4]. OpenConfig has a data model named as *optical-wavelength-router*, which contains a definition on a configurable switching element, related to a wavelength selective switch (WSS), a key component of a ROADM. However, this data model is too simple to describe ROADM in real field implementation and operation. It does not provide a description of the full attributes of a WSS, such as WSS name, ports number, optical power on each port, and control mode for each media channel. In addition, this model doesn't characterize properties of a ROADM as a node, such as detailed degree information and operation on media channels in terms of degrees.

To solve these problems, we first augment OpenConfig's data model of *optical-wavelength-router* to make it capable to describe WSS components. This model includes two parts, one is for component itself and the other is for media channel management. For the former part, except for the name of WSS, all the other items are related to port states, e.g. number of input ports and output ports, which are compatible with both 1*N or M*N WSS. For each port, it includes port name, optical power, and a container named as *far-end-info*, including both chassis and port name on the other side. For the latter part, frequency slots within one media channel are introduced to enable both network media channel operation and optical domain equalization of a media channel. Besides that, the control mode of each frequency slot is defined. "*ATTENUATION-CONTROL*" mode means directly adjusting the attenuation value of a WSS. "*POWER-CONTROL*" mode is to define a *target-power-value* for each frequency slot. In the state container, *actual-power-value* shows the current power of this frequency slot, usually obtained from an optical channel monitor (OCM). The detailed Yang file on media channel is shown in Fig. 1(a). With such model, WSS can be accessed by the ODL controller through NetConf interface, as shown in Fig. 1(b).

Second, we develop a ROADM node controller to communicate southbound with optical line system devices including WSS by calling the REST interfaces provided by ODL controller, and exposes REST interface to the SDN network controller, as shown in Fig. 1(b). There are three main functionalities inside this ROADM node controller. Degree management is responsible to map the physical device/line-card/component to abstracted degree ID through chassis-name and component list. Connection management stores all the intra-node physical connections. Each connection is identified by the source/destination degree and port. As a result, media channel is maintained in ROADM node controller by source/destination degree, lower/upper frequency, together with power control mode which is similar as that in WSS data model. For each operation on media channel, node controller translates the degree information into device name and port name, and then generate a set of API calls with proper parameters, such as media channel details and corresponding WSS port name.

```
+--rw media-channel* [index]
   +--rw index     -> ../config/index
   +--rw config
   |  +--rw index?             uint32
   |  +--rw name?              string
   |  +--rw lower-frequency?   oc-opt-types:frequency-type
   |  +--rw upper-frequency?   oc-opt-types:frequency-type
   |  +--rw admin-status?      oc-opt-types:admin-state-type
   |  +--rw source
   |  |  +--rw port-name?   -> /oc-platform:components/component/name
   |  +--rw dest
   |  |  +--rw port-name?   -> /oc-platform:components/component/name
   |  +--rw frequency-slots
   |     +--rw frequency-slot* [lower-frequency upper-frequency]
   |        +--rw lower-frequency       oc-opt-types:frequency-type
   |        +--rw upper-frequency       oc-opt-types:frequency-type
   |        +--rw control-mode?         identityref
   |        +--rw attenuation-value?    decimal64
   |        +--rw target-power-value?   decimal64
   +--ro state
      +--ro index?             uint32
      +--ro name?              string
      +--ro lower-frequency?   oc-opt-types:frequency-type
      +--ro upper-frequency?   oc-opt-types:frequency-type
      +--ro admin-status?      oc-opt-types:admin-state-type
      +--ro source
      |  +--ro port-name?   -> /oc-platform:components/component/name
      +--ro dest
      |  +--ro port-name?   -> /oc-platform:components/component/name
      +--ro oper-status?       identityref
      +--ro channel-power?     decimal64
      +--ro frequency-slots
         +--ro frequency-slot* [lower-frequency upper-frequency]
            +--ro lower-frequency       oc-opt-types:frequency-type
            +--ro upper-frequency       oc-opt-types:frequency-type
            +--ro control-mode?         identityref
            +--ro attenuation-value?    decimal64
            +--ro target-power-value?   decimal64
            +--ro actual-power-value?   decimal64
```

(a)



(b)

Fig. 1. (a) Media channel data model in an augmented *optical-wavelength-router* Yang file. (b) Hierarchical control structure of disaggregated transport networks. Augmented data model is realized by WSS device, and ROADM node controller is placed between OpenDayLight controller and SDN network controller. OA: optical amplifier, OCM: optical channel monitor, APS: automatic protection switch.

2. Demonstration Procedure

The demo is on a ROADM network with three ROADM nodes as shown in Fig. 2(a). Three ROADM nodes are located in two racks, and they are connected with each other, as shown in Fig. 2(b). A ROADM device has one chassis with two-rack-unit height, and it can support four cards from slot 1 to slot 4. Each card represents a ROADM degree, which consists of a twin WSS with 20 tributary ports, optical amplifiers and a protection switch module. In node R_1, we separate three degrees into two ROADM chassis intentionally to demonstrate the management ability of node controller on multiple chassis. The other two nodes, R_2 and Z_1, use a two-degree ROADM (D_1 and D_2). Intra-node connections between different degrees are pre-defined by the fiber shuffle. For example, in node R_1, degree D_1 connects to D_2 on port 3#, and its 6th port is connected to degree D_5. To simplify the ROADM operation, we use a full band optical mux/de-mux for each degree to act as the local add drop unit, and terminals are connected to it directly. In our setup, we choose three terminal transponders from different vendors. Their net capacities are 200, 400 and 600 Gb/s, with bandwidth of 50, 100 and 100 GHz, respectively. We have arranged three light paths, as shown in Fig. 2(c). For the 200 Gb/s transponder, the light path starts from node A_1, which is a non-ROADM node, passes through R_1 and R_2, and finally reaches the destination at Z_1, denoted by the green dash line in Fig. 2(b). The 400 Gb/s light path is relatively shorter, and only passes two ROADM nodes, R_1 and Z_1. The 600 Gb/s has the highest optical signal to noise ratio (OSNR) limit, so it runs only one link from R_2 to Z_1. The link loss between each two nodes are 25.0 dB controlled by fixed attenuators. Notice that all the light paths are bidirectional.

The demonstration includes all the operations related with ROADM node controller: creating and deleting a degree, creating and deleting a media channel, modifying the target power of a media channel, and changing the control mode of media channel. At the beginning, all the devices are mounted to the ODL controller. The demo starts with creating degrees for each ROADM node. Then each optical channel (OCH) listed in Fig. 2(c) is set up step by step. Take 200 Gb/s OCH as an example. The center frequency is 194.10 THz with bandwidth as 50 GHz. At node R_1, a media channel follows this information is configured as shown in Fig. 3(a). The similar action is processed in the successive nodes, R_2 and Z_1. After media channel is occupied along the light path, the terminal's output is enabled. Then we adjust the media channel's attenuation along the light path by setting proper "*target-power-value*". The NetConf response of WSS is shown in Fig. 3(b). After the output power is locked, we change the media channel control mode from "*POWER-CONTROL*" to "*ATTENUATION-CONTROL*". When all the media channels finish configuration, the end-to-end OCH is successfully set up and pre-forward-error-correction bit error ratio can be queried from the terminal device.

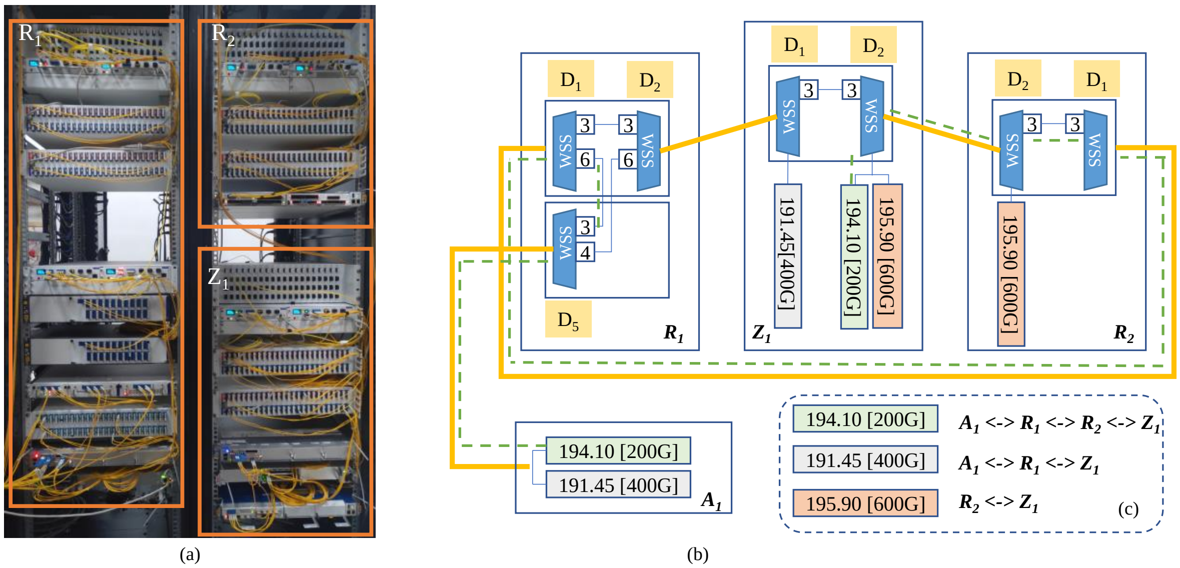


Fig. 2. (a) Two racks with three ROADM nodes, R_1, R_2 and Z_1. (b) Detailed diagram of demonstrated ROADM networks. A_1 is a simple node with two terminals. A_1 is connected to degree D_5 of R_1, which is composed by two ROADM devices. Both R_2 and Z_1 are ROADM nodes with two degrees. (c) Bidirectional light paths for 200 Gb/s, 400 Gb/s and 600 G/s terminals, respectively.

Configure media channel to node controller


```
{
  "name": "express-ROADM001-A-001-AL-R-002/1/1/WSS/WSS_TRIB_OUT_3--ROADM001-A-00AL-R-001/1/1/WSS/WSS_TRIB_IN_6 $194075--194125",
  "oadm_name": "ROADM001-A-001",
  "type": "express",
  "source_degree": 5,
  "dest_degree": 1,
  "lower_frequency_ghz": "194075",
  "upper_frequency_ghz": "194125"
}
```


(a)

NetConf response from device


```
<media-channel>
  <index>111</index>
  <config>
    <dest>
      <port-name>PORT-1-1-1-WSSCOMMONDROP</port-name>
    </dest>
    <upper-frequency>194125000</upper-frequency>
    <source>
      <port-name>PORT-1-1-1-WSSADD6</port-name>
    </source>
    <frequency-slots>
      <frequency-slot>
        <lower-frequency>194075000</lower-frequency>
        <upper-frequency>194125000</upper-frequency>
        <attenuation-value>0.0</attenuation-value>
        <control-mode>SET-TARGET-POWER</control-mode>
        <target-power-value>3.0</target-power-value>
      </frequency-slot>
    </frequency-slots>
    <index>111</index>
    <lower-frequency>194075000</lower-frequency>
  </config>
```

```
  <state>
    <index>111</index>
    <name>111</name>
    <lower-frequency>194075000</lower-frequency>
    <upper-frequency>194125000</upper-frequency>
    <admin-status>ENABLED</admin-status>
    <oper-status xmlns:oc-platform-types="http://opencon
    <channel-power>3.22</channel-power>
    <source>
      <port-name>PORT-1-1-1-WSSADD6</port-name>
    </source>
    <dest>
      <port-name>PORT-1-1-1-WSSCOMMONDROP</port-name>
    </dest>
    <frequency-slots>
      <frequency-slot>
        <lower-frequency>194075000</lower-frequency>
        <upper-frequency>194125000</upper-frequency>
        <control-mode>SET-TARGET-POWER</control-mode>
        <attenuation-value>6.4</attenuation-value>
        <target-power-value>3.0</target-power-value>
        <actual-power-value>3.22</actual-power-value>
      </frequency-slot>
```


(b)

Fig. 3. (a) Response of node controller's API when configure a media channel. (b) NetConf response from device when set the control mode of media channel to "*POWER-CONTROL*" mode.

3. Innovation

An open and disaggregated transport system with ROADM benefits operators in metropolitan areas. OpenConfig does not provide a full operation model for a ROADM. We have demonstrated an augmented data model for WSS based on *optical-wavelength-router* and a node controller to manage a multi-chassis ROADM node. Those two innovations are verified in a 3-node ROADM system with terminal transponders from different vendors, and the demonstration proves the efficiency in both ROADM management and service configuration.

4. OFC Relevance

Open and disaggregated optical transport systems have been a hot topic for several years at OFC. The proposed demo will be of interest to both network operators who use ROADMs in their networks and device/system vendors who provide WSS related products. The disclosed data model on WSS and realization details in node controller will provide a guidance in implementing open and disaggregated ROADM networks.

5. Reference

[1] M. Filer, H. Chaouch, and X. Wu, "Toward Transport Ecosystem Interoperability Enabled by Vendor-Diverse Coherent Optical Sources Over an Open Line System," J. Opt. Commun. Netw. 10, A216-A224 (2018)

[2] J. Babbitt, "Optical DCI Architecture: Point-to-Point versus ROADM," Lightware, https://www.lightwaveonline.com/data-center/data-center-interconnectivity/article/16673421/optical-dci-architecture-pointtopoint-versus-roadm, Aug 5, 2017

[3] Y. Yin, T. Wang, L. Dou, S. Zhang, M. Xia, C. Xie, "Standardized Northbound Interface Testing Automation on the Open and Disaggregated Optical Transport Equipment," in Optical Fiber Communication Conference (2019), paper M3Z.3.

[4] http://www.openconfig.net/.