Demonstration of a Disaggregated ROADM Network with Automatic Channel Provisioning and Link Power Adjustment

Huan Zhang[1], Fan Gao[1*], Jingchi Cheng[1], Liang Dou[2], Sai Chen[1], Boyuan Yan[1], Zhao Sun[2], Lei Wang[2], Chongjin Xie[3]

(1) Alibaba Cloud, Alibaba Group, Hangzhou, China, *chufan.gf@alibaba-inc.com
(2) Alibaba Cloud, Alibaba Group, Beijing, China, (3) Alibaba Cloud, Alibaba Group, Sunnyvale, USA

Abstract *We design and implement a disaggregated ROADM network by treating an optical multiplex section as a basic building block. Both automatic channel provisioning and end-to-end link power adjustment are demonstrated in such network.*

Overview

Open and disaggregated optical network technology began to be adopted by hyper-scale data center operators for data center interconnect (DCI) applications a few years ago[1][2]. The technology gives operators not only the freedom to select best-in-class components to build their networks, but also the potential to control and operate their networks more efficiently. Today's deployed open and disaggregated systems are mainly open-line systems (OLSes), which are disaggregated from optical terminal equipment. In such systems, optical terminal equipment from different vendors can co-exist, but the whole line system usually come still from one vendor. While OLSes are suitable for metro point-to-point networks that consist of a few spans, they may not be appropriate for reconfigurable-optical-add-drop-multiplexer (ROADM) based long-haul and metro mesh networks.

To further disaggregate an OLS, the Open ROADM Multi-Source Agreement (MSA) was formed[3]. The Open-ROADM defines the interoperability specifications for ROADMs, including inline amplifiers (ILAs), dynamic gain equalizers (DGEs), with the goal to disaggregate and open up traditionally proprietary ROADM systems and enable the software-defined-networking (SDN) control of ROADMs. Lots of work has been done by the Open ROADM MSA, and it helps enrich the ecosystem for optical transport networks. Due to the complexity of line systems, fully interoperability of line systems is not mature for field deployment yet. Currently, it may not be of much value for an operator to break an OLS into too many pieces, as it increases the control layer complexity to adapt different device behaviors from different vendors, and some nice proprietary features for transmission section controls may be lost.

In this demo, we propose and demonstrate a new technique to build up a disaggregate ROADM network. We treat an optical multiplex section (OMS) as a closed section, in which all the equipment is from a single vendor, and decouple different OMSes in the network. As a result, the whole network may consist of several OMSes and each OMS or OMS group may belong to a different vendor. Using this technique, we are able to keep some nice proprietary features in an OMS from vendors and at the same time avoid lock-in to a vendor. To make this technique work, we designed an optical cross connect (OXC) fiber shuffle to connect each wavelength-selective switch (WSS) with vendor specific fiber interface from each degree of a ROADM, as shown in Fig. 1(a). With the OXC fiber shuffle, vendor specified WSS on each degree is physically connected to make up a disaggregated ROADM node. One challenge to manage a disaggregated ROADM network is network layer management and the control of optical signals in optical transmission lines. OpenConfig defines data models to regulate the north bound interfaces for most of the devices and functionalities[4]. By augmenting on the existed OpenConfig models, we designed node layer management model for ILA, DGE, and ROADM[5]. Base on that, a network layer control algorithm was developed to manage the power adjustment of each device along an optical link comprised of OMSes from different vendors.

During power adjustment, we manage optical channels (OCHes) by OCH groups. An OCH-group is a collection of OCHes that are from the same source and to the same destination, sharing the same fiber route. During the adjustment, OMSes irrelevant to this OCH-group will not be touched. For each round of power adjustment, the target power at every point along a route is pre-calculated with an engineering planning tool.

In order to reduce service impact during power adjustment, we propose and demonstrate an automatic power adjustment method that keeps OCH margin at a certain level. Because most of the components along the optical link work under a gain or fixed attenuation mode, any variation on the power setting point will cause power changes

978-1-6654-3868-1/21/$31.00 ©2021 IEEE

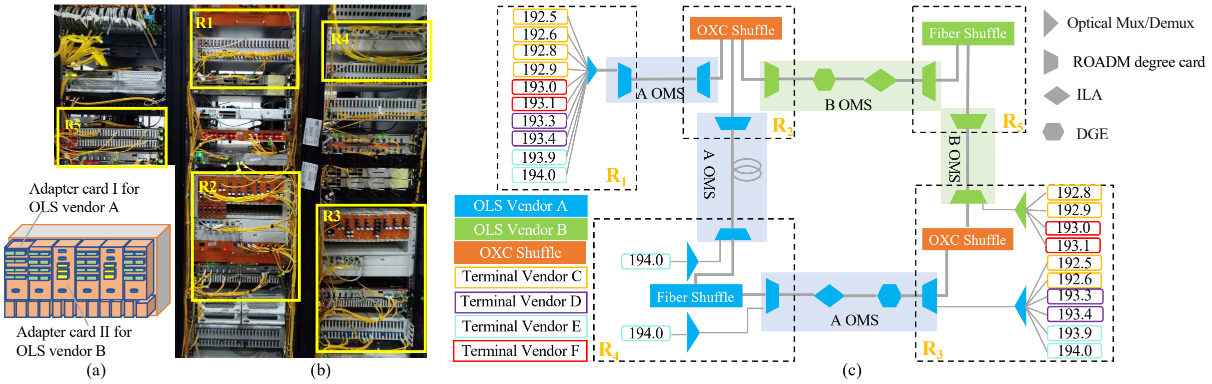

Fig. 1. (a) Schematic diagram of OXC fiber shuffle with two kinds of adapter cards to connect with ROADM degrees from Vendor A and B. (b) Demo setup for a disaggregated ROADM network with 5 ROADM nodes. (c) Network topology of the ROADM network. R1 is a single-degree ROADM, R2 and R3 are disaggregated ROADMs connected with the OXC fiber shuffle. R4 and R5 are ROADMs from a single vendor. There are 5 OMSes with colors as background, 3 of them are from vendor A and the other 2 are from vendor B. 10 OCHes are added, 4 OCHes with a route of R1<->R2<->R5<->R3; 5 OCHes with a route of R1<->R2<->R4<->R3; 1 OCH with a route of R1<->R2<->R4; and 1 with a route of R4<->R3.

on subsequent links, and it is critical to select an appropriate adjust step for each power setting point. First, the target power is not configured directly, but approached by an iteration process with an adaptive step size. Second, to keep service error free during adjustment, the step size is strictly limited by checking the generalized optical signal-to-noise ratio (GOSNR) margin generated from bit error ratios before forward-error correction (pre-FEC BERs) of each involved OCHes. Note that the relationship between power adjust steps and GOSNR margins can be different for linear and nonlinear limited scenarios. According to the Gaussian Noise Model, the GOSNR of an OCH can be expressed as[6]:

$$GOSNR \approx \frac{P_i}{P_{ASE}+\eta P_i^3} \qquad (1)$$

where P_i is the launch power, P_{ASE} is the amplified spontaneous emission (ASE) noise of optical amplifiers, and η is the nonlinear interference coefficient. The equation shows that the GOSNR will decrease by 1 dB for an ASE-noise-limited OCH when the launch power is reduced by 1dB, but 2 dB for a fiber-nonlinearity-limited OCH when the launch power is increased by 1 dB. Considering the different impacts of linear and nonlinear OSNR, different margin thresholds may be used for different tuning direction.

Demonstration Procedure

As shown in Fig. 1, the demo configuration is a disaggregated ROADM network with five ROADM nodes, two ILA nodes, two DGE node and several terminal devices with 22 line ports from different vendors. Those devices allocate in three racks as shown in Fig. 1(b). Fig. 1(c) shows the network topology. The ROADM sites are marked as Rn where R1 is a single degree ROADM, R3, R4 and R5 are two-degree ROADMs, R2 is a three-degree ROADM. Among these ROADMs, R2 and R3 are disaggregated with degrees from two different vendors. Although their degree cards both support the 20 tributary ports, the connectors are totally different, e.g., vendor A selects MPO-12 and vendor B uses MPO-24. In these two sites, degree cards are connected through OXC shuffle. Fig. 1(a) shows the schematic diagram of an OXC fiber shuffle, which realizes full connections among different degrees and the pluggable adapter cards are used to adapt to different vendor's ROADM card. We use an optical mux/demux for each degree on R1, R3 and R4 to act as the local add-drop unit, which are directly connected to terminal transponders. In this setup, 11 pairs of terminal transponders with net bit rates of 400 Gb/s and 16-ary quadrature-amplitude modulation (16QAM) format from four different vendors are used. In order to simulate different operations in a real mesh network, we connect the OCHes terminals as shown in Fig. 1(c). Ten OCHes are connected at R1 and R3. At R3 four OCHes are connected on vendor B ROADM degree, and six OCHes are connected on vendor A ROADM degree. Two OCHes connected on each degree of R4, with a central frequency of 194.00THz.

We demonstrate two power management scenarios over this network. The first one is green field channel provision. In this scenario, we add four new OCHes with central frequencies of 192.8 THz, 192.9 THz, 193.0 THz and 193.1 THz through R1, R2, R5 and R3 in sequence. The second scenario is for brown field link power adjustment, to simulate a case in a real system that the transmission performance needs to be re-optimized after transmission condition is modified, e.g., fiber degradation, link repairment or channel load variation. In this demo scenario,

978-1-6654-3868-1/21/$31.00 ©2021 IEEE

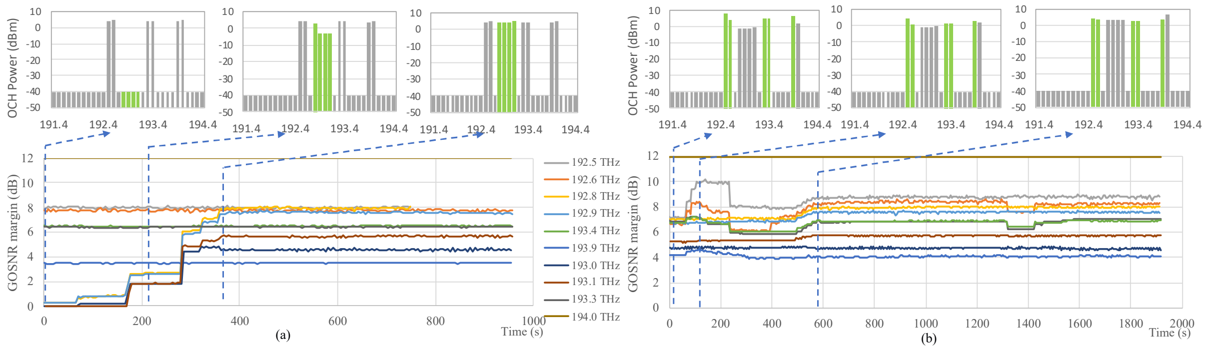

Fig. 2. GOSNR Margin variation for OCHes during automatic power adjustment, with upper part shows OCM spectrum on R1 ingress direction at different time slot. (a) Green field provision scenario, where four new channels are deployed with target powers after automatic power adjustment. (b) Brown field adjustment scenario, where five channels meet their target powers after automatic power adjustment without service impact.

the optical power of a 5-channel OCH-group route through R1, R2, R4 and R3, with central frequencies of 192.5 THz, 192.6 THz, 193.3 THz, 193.4 THz and 193.9 THz, are deviated from their targets by 4~8dB intentionally. In this case, GOSNR margins and optical channel monitor (OCM) spectrums of all involved OCHes are continuously monitored during power adjustment to avoid any service interruption.

In demo environment, a network management system (NMS) is used to trigger the adjustment, record and display the real time OCM and GOSNR margin. In this case once the automatic adjustment is triggered, the algorithm will first run the adjustment starts from R3 to R1 and then back from R1 to R3 with OCH-group's route in an iteration cycle. During the adjustment, GOSNR margin and the channel power obtained by OCM at R1 ingress are shown in Fig. 2. In the green field provision scenario, the new channels at 192.8 THz, 192.9 THz, 193.0 THz and 193.1 THz are initially blocked with a 0-dB GOSNR margin. Then the adjustment algorithm automatically turns on this OCH-group and adjusts to reach their target power of 4.5 dBm. For the brown field adjustment, an OCH-group with five OCHes at 192.5 THz, 192.6 THz, 193.3 THz, 193.4 THz and 193.9 THz central frequencies are existing channels with channel powers deviated from target. During the adjustment, the margin for existed channels are monitored and optimized to reach their target power gradually.

Fig. 2 also shows that in both scenarios, the automatic power adjustment algorithm takes about 10 minutes to stabilize for one direction, and furthermore, since the adjustment for each channel are parallel, it is estimated that the time-consumption for a fully load system can also be stabilized on a few minutes.

Innovation

How to control and manage optical channel powers along an optical transmission link comprised of network elements from different vendors in a disaggregated ROADM network is a challenge. To the best of our knowledge, this is the first demonstration of an automatic end-to-end optical channel provisioning and power adjustment in a disaggregated ROADM network in the literature.

ECOC Relevance

Open and disaggregated optical transport systems have been a hot topic at ECOC. Almost all the demonstrated open and disaggregated systems are point to point. This demo demonstrates a disaggregated ROADM-based optical mesh network with an automatic end-to-end optical channel provisioning and power adjustment. It provides a guidance on how to set up and manage an open and disaggregated ROADM network, and will be of interest to both network operators who use ROADMs in their networks and device/system vendors who provide related products.

Reference

[1] C. Xie, L. Wang, L. Dou, M. Xia, S. Chen, H. Zhang, Z. Sun, and J. Cheng, "Open and Disaggregated Optical Transport Networks for Data Center Interconnects" J. Opt. Commun. Netw. 12, C12-C22, (2020).

[2] V. Kamalov, V. Dangui, T. Hofmeister, B. Koley, C. Mitchell, M. Newland, J. O'Shea, C. Tomblin, V. Vusirikala and X. Zhao, "Lessons learned from open line system deployments," OFC'2017, paper M2E.2 (2017).

[3] http://openroadm.org/

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

[5] L. Dou, L. Wang, S. Chen, J. Cheng, Z. Sun, M. Xia, H. Zhang, L. Xiao, J. Xu, J. Yu, C. Xie, "Demonstration of Open and Disaggregated ROADM Networks Based on Augmented OpenConfig Data Model and Node Controller," OFC'2020, paper M3Z.12 (2020).

[6] Daniel Semrau, Robert I. killey, and Polina Bayvel. "The Gaussian Noise Model in the Presence of Inter-Channel Stimulated Raman Scattering," J. lightwave technology. Vol.. 36 No. 14 JULY 15 (2018)