Optical Network Virtualization using Multi-technology Monitoring and Optical Virtualize-able Transceiver

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Abstract: We introduce multi-technology transport layer monitoring to facilitate coordinated virtualization of optical and packet networks supported by optical virtualize-able transceivers. The scheme is experimentally demonstrated to show a holistic configuration across both layers.
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1. Introduction

Optical network virtualization is one of the key enablers [1] to support future high-performance network-based applications that have different quality of service requirements and network access patterns. An optical virtualize-able transceiver (V-BVT) [2] has been proposed recently as an equipment-level virtualization technology in supporting the optical network virtualization. It enables the creation of virtual transceivers based on the on-demand selection of its local infrastructure resources, in order to support multiple co-existing but isolated virtual optical networks (VONs). On the other hand, optical networks have analogue constraints and impairments, which have a great impact in accommodating VONs. Although a physical layer impairment-aware model [3] has been studied and introduced into the optical virtualization, this method relies more on analytical estimation and lack of adaption, e.g., it can't deal with undesirable and time-varying loss/excessive noise that causes a big degradation in the optical channel quality of transmission (QoT). Besides, due to diverse applications types; traffic from these applications varies dynamically with time, which in turn greatly affects the allocation of virtual link resources to support the transmission of these applications. Thus, it is important to introduce real-time monitoring across all the network layers as a key role in the virtualization process. Multi-technology monitoring can obtain up-to-date characteristics of the optical transport layer, e.g., optical link QoT, as well as the packet transport layer, e.g., packet size and deep packet inspections. By interacting with the control and management system, the multi-technology real-time monitoring scheme further facilitates coordinated virtualization of the packet transport network and optical transport network in order to achieve a holistic optimization in the optical layer and configuration in the packet layer.

In this paper, for the first time, we introduce multi-technology transport layer monitoring, specifically both optical layer and Ethernet monitoring into the optical network virtualization that is supported by V-BVT. We also propose a new scheme in the SDN-enabled control plane to facilitate the optimization of coordinated virtualization by applying monitoring and utilizing V-BVT. Then, we experimentally demonstrate the proposed scheme to show the re-configuration of packet layer resources and the optimization of V-BVT resources allocation and QoT maintenance.

2. Optimization of optical virtualization scheme using monitoring and V-BVT

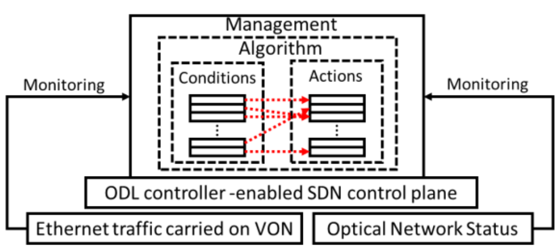

Fig.1. The application for V-BVT resource allocation and monitoring

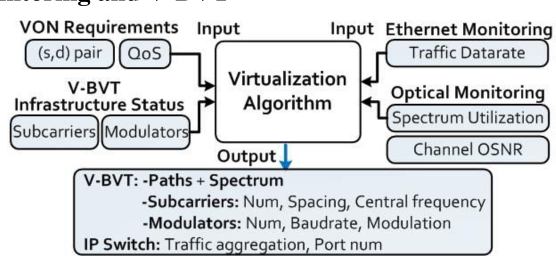

Fig.2. Inputs and outputs of V-BVT virtualization algorithm

Our proposed optical virtualization scheme utilizes the V-BVT and multi-technology monitoring. V-BVTs are placed at the edge of the optical network and each contains a local infrastructures pool, i.e., optical subcarriers pool and optical modulators pool. It can create multiple virtual transceivers based on the requirement of VON demands, the availability of its local infrastructure pool, and the optical network status. The monitoring system periodically fetches up-to-date information, including real-time Ethernet traffic data rate, optical link spectrum utilization and channel OSNR from the optical network status for all VONs. All of this information is sent to a management block on top of the SDN-enabled control plane with an extended OpenDayLight (ODL) controller. The management block acts as a non-injective and non-surjective function, where multiple conditions may have the same action (and actions with nonactive conditions). Any variation of information sent by the monitoring system affects the V-BVT resource selection in creating virtual transceivers, e.g., modulation format and baud rate, the subcarriers central frequency and number, etc. So, when a variation is detected by the monitoring system, the management block will activate an action with a set of configurations, such as the change of optical channel selection.

The inputs and outputs of the management block, which contains a virtualization algorithm are briefly shown in Fig. 2. Apart from the aforementioned monitoring information from the optical and packet layers, the management block can also obtain the VON requirements and infrastructure status from the V-BVTs. The management block outputs the decision based on the objective to maximize VONs accommodation, and the decision includes the optical path selection and infrastructure selection in the V-BVTs, as well as the aggregation of services at the packet layer.

For our specific scenarios in the experimental demonstration, more details inside the management block are shown in the flowchart in Fig. 3. The first demonstration is to accommodate two new incoming services based on their data rate requirements and the source and destination pair shown in Fig. 3(a). Following, in Fig. 3(b)-condition a., we introduce Ethernet monitoring, to demonstrate the optimized utilization of the Ethernet switch resource and V-BVT infrastructures when accommodating these two services. Then in Fig. 3(b)-condition b., we introduce optical layer monitoring to show the re-creation of virtual transceivers from V-BVTs to support the same service when existing accommodation of a selected channel failed due to the undesired optical network impairments.

3. Experiments and Results

The experimental setup for demonstrating the scheme and the aforementioned scenarios are shown in Fig. 4. A similar set-up in [2] is used for implementing the V-BVTs, where the subcarriers pool is settled using a tunable mode-lock laser (TMLL). After applying the fibre delay interferometer (DI), around 25 optical subcarriers are selected in the spacing of 20 GHz and are sent to the input port A of the 4×16 wavelength selective switch (WSS-1). When setting up the modulator's pool, a collection of different modulators are pre-connected to the output ports of the WSS-1, including PM-16-QAM (10, 20, 28 GBd), BPSK (10, 40 GBd) and 10 GBd PM-QPSK. Different virtual transceivers are created after selection of subcarriers and modulations. After sending their spectrum into the other 4×16 WSS-2, the traffic that each virtual transceiver carriers can be directed onto same/different paths by selecting the output ports. The simplified optical network topology is settled using a 192×192 optical space switch and coherent receivers are adopted to obtain the BER and constellations.

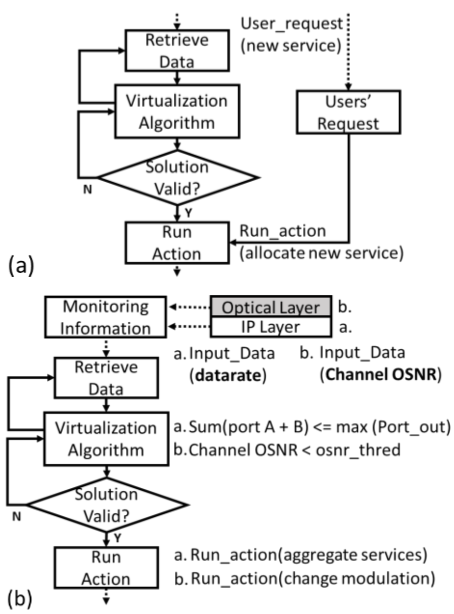

Fig.3. Scenario: (a) accommodating new services, (b) reconfiguration by monitoring Ethernet and optical layers

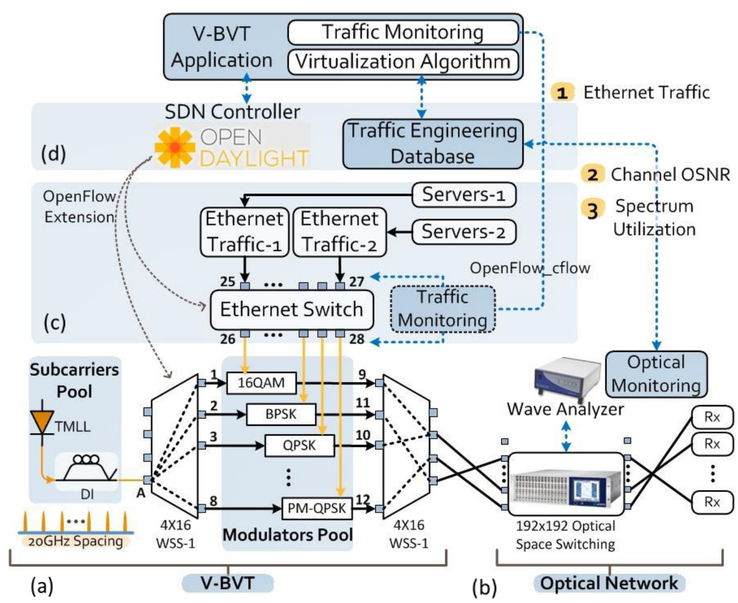

Fig.4. Experimental Platform: (a) V-BVT construction, (b) Arbitrary Network topology configuration using Polatis, (c) packet layer configuration, (d) ODL enabled control plane with developed application

The monitoring of the optical link in the network topology is performed by applying the optical wave analyzer (WA) that can offer 150 MHz resolution to obtain the OSNR values of each operational channel and the channel utilization on the link. The monitored information is updated into the traffic engineering database (TED). The two inputs to the Ethernet switch are sent by the traffic generator to emulate the traffic from different servers. Each of the switch output ports are pre-connected to each modulator in the modulators pool through opto-electronic convertors to enable selection of modulators for the Ethernet traffic. The Ethernet monitoring is performed at the switch input and output ports and the monitored real-time Ethernet traffic data rate variations are retrieved by the traffic monitor block in the application. The monitoring information from both TED and traffic monitor block is sent into the virtualization algorithm inside the application for facilitating the decision.

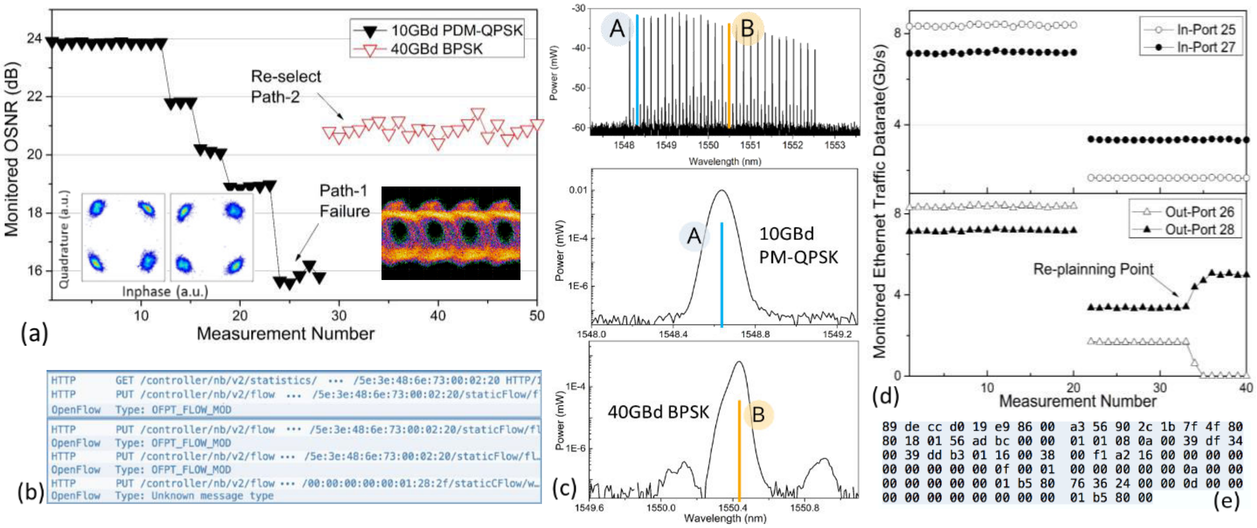

Fig.5. Real-time monitoring information: (a) monitored optical link OSNR dropping with modulation format re-selection, (b) flow messages for reconfiguring V-BVT, (c) the selected subcarriers from the subcarriers pool, and the corresponding two modulated spectrum, (d) monitored Ethernet traffic at input and output ports of switch, with traffic aggregation, (e) OpenFlow message for configuring WSS

Fig. 5 (a) shows the OSNR monitoring from the WA. For the current service, 10 GBd PM-QPSK is selected to accommodate the 40G data rate traffic using wavelength 1548.74 nm selected from the subcarriers pool (Fig. c. upper) in the colored tone A**.** The original channel OSNR is high quality around 24 dB, and when this channel quality decreases gradually below the OSNR threshold of 15 dB, the failure alarm is triggered in the management block, and the reconfiguration of modulation is activated. A newly decided modulation together with the new channel will be selected from the V-BVT subcarrier pool, and this service is accommodated using 40 GBd BPSK on channel 1550.50nm in the colored tone B (Fig. c. lower). The monitored OSNR of the new channel figure in Fig. 5 (a) is 20dB, where the constellation (before reconfiguration) and the eye diagram (after reconfiguration) of the modulation formats are also shown. The spectrums of the created transceiver slices are shown in the lower 2 plots of Fig. c.

Fig. 5 (d) shows the monitoring of the Ethernet traffic at the switch. The upper-plot illustrates the monitored traffic data rate of 8.6 Gb/s at input port 25 and 7.2 Gb/s at port 27. Meanwhile, the lower-plot indicates the corresponding traffic of around 8.6 Gb/s and 7.2 Gb/s at output ports 26 and 28, respectively. In this condition, the two services are supported by two separate ports of Ethernet switch, as well as the two individual modulators and subcarriers from V-BVTs on separate channels. When the condition changes, as the traffic at input pot 25 and 27 dropped less than 2 Gb/s and 3.4 Gb/s, the management block activates the traffic aggregation action. This allows the two services to be accommodated by only one switch output port, and V-BVT only needs to create one virtual transceiver to support the two services using one modulator and a single subcarrier. Fig. All the above switch and V-BVT re-configurations are conducted using OpenFlow (OF) message through ODL controllers shown in Fig 5. (b) and (e).

4. Conclusion

We have experimentally demonstrated the proposed optical virtualization scheme utilizing V-BVTs and real-time monitoring in optical and packet transport networks, for the first time. This scheme achieves optimization in V-BVT optical infrastructures and reconfiguration of Ethernet switch resources through ODL controller, during on-demand creation of virtual transceivers.

Acknowledgement

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5. References

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