Demonstration of a SDN-based Spectrum Monitoring of Elastic Optical Networks

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Abstract
We demonstrate optical channel monitoring capabilities executed as SDN applications. To guarantee Quality of Transmission, diagnostic is performed by dynamically selecting the list of optical parameters to be monitored and by adjusting their polling rates.
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1. Overview

Elastic optical networks are driven by advances in software defined network (SDN) controllers, tunable optical network fabric as well as automated network operations [1]. Optical channels are going to be provisioned on-demand by SDN controllers as easily as the deployment of IT services. To this end, the monitoring of optical parameters characterizing each optical channel is fundamental.

In this demo, we show an optical network controller built on ONOS 1.7 [2] able to perform quality of transmission (QoT) monitoring of optical connections (L0 flows) [3] and to dynamically react to performance degradation through automatic network reconfiguration. Each L0 flow setup is handled by an Optical Intent developed and integrated in ONOS which solves the routing and spectrum assignment problem [4]. The demo will present all the components and extensions needed by SDN network controller to allow QoT monitoring of L0 flows. We extend Port Statistic Request and Reply messages introduced in the OpenFlow 1.4 (OF) protocol to retrieve statistics and state information related to optical ports of reconfigurable optical add-drop multiplexers (ROADMs). Three novel components are introduced: OF extensions, a Monitoring Intent (MI), and a QoT Monitoring application (QMA).

2. Innovation

We enriched the Port Statistic Reply with new parameters about transmitter and receiver associated to an optical port. We extended Request and Reply OF messages to offer the new possibility to retrieve only a portion of parameters. In addition, for each parameter in the model, these new extensions provide instant values and statistics, i.e. average, variance, minimum and maximum to enable devices to compute statistics locally and offload the control channel. Finally, a 32-bit flag was added to both Request and Reply to allow devices to indicate which parameters are requested and supported respectively.

OF protocol enables the controller to collect monitored information from the connected devices, however it does not describe the strategy followed by the controller to gather the monitored parameters. To this aim we proposed and implemented inside the controller a MI. The MI selects the parameters the controller should collect from the ROADMs as well as the polling rate in order to avoid overloading the control channel with unnecessary message exchanges. The decision taken by the MI depends on the requirements of the monitoring applications that are subscribed to the network controller. In our use case the MI gathers information about the bit error rate (BER) and optical spectrum parameters at the input of the destination ROADM. These values are processed and stored in a database managed by the controller.

The QMA monitors the QoT evolution, more precisely the BER, and reacts to a QoT degradation by issuing commands to the controller in order to trigger appropriate network reconfiguration. We developed generic notification mechanism relying on the RabbitMQ protocol in the northbound interface of ONOS to advertise when a given parameter crosses a certain threshold and to which the application must subscribe. The subscribe message consists in the parameter name, the L0 flow identifier, and the threshold value. The QMA subscribes to the controller to receive BER notifications. Once the QMA receives a notification, it will request monitored parameters from the controller, in our case the received spectrum. Finally, the QMA triggers a specific reconfiguration if needed.

3. OFC relevance

During the demo, we will have the opportunity to explain, show and comment the SDN-based spectrum monitoring to the OFC audience, in particular how we propose to retrieve only a portion of monitored parameters. We will base the demo on the proposed application, ONOS-based SDN controller included our monitoring intent and 2 Raspberry Pi emulating the source and destination nodes. In addition, we will show a recorded video with optical hardware as fully detailed below.

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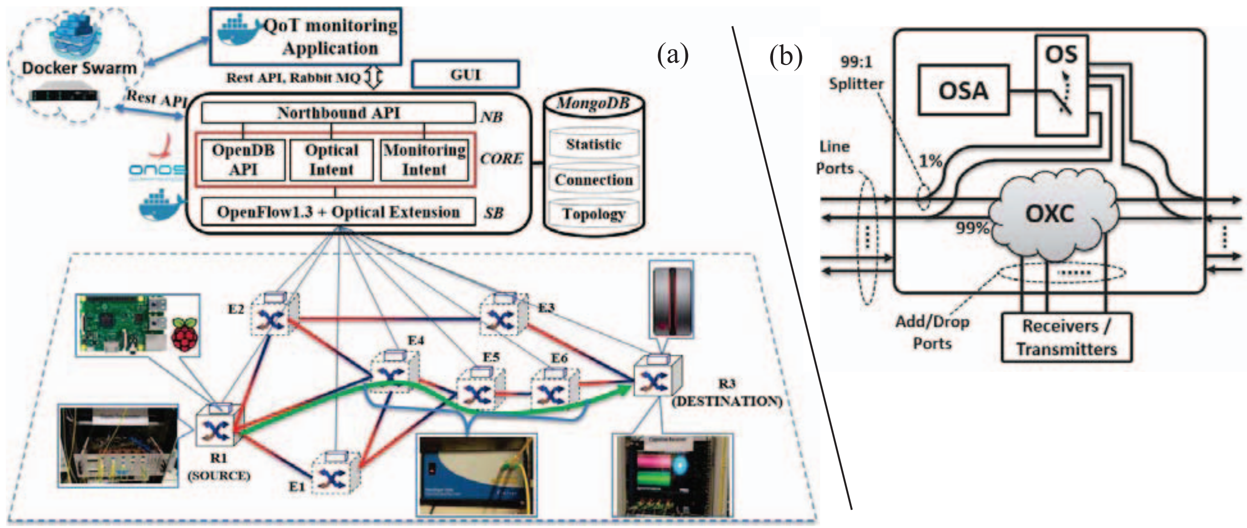

Figure 1. (a) Experimental testbed. (b) Spectrum monitoring setup inside a ROADM.

The testbed of the recorded video is shown in Figure 1a. The network is composed of 8 ROADMs: two of them, the source and destination, are physical hardware; the three ROADMs cascade across the established L0 flow is emulated through a Finisar WaveShaper 1000s; and the remaining ones are emulated with Mininet [5]. The source node is composed of a coherent transmitter [6] controlled by an OF agent embedded in a Raspberry Pi. The destination node, also controlled by an OF agent, consists in a coherent receiver (oscilloscope WaveMaster 830Zi-A plus offline digital signal processing) at the drop port, and an optical spectrum analyzer (OSA) (Wave Analyzer 1500S) connected to each input and output port through a 1% splitter addressable thanks to an optical switch (OS) (Figure 1b).

Our scenario starts by configuring an L0 flow through ONOS GUI specifying the source and destination nodes, the requested data rate and, the required QoT. In parallel, the controller, sends a request to the orchestrator (Docker SWARM) [7] to deploy the QMA. Then, the QMA subscribes to the BER notification (as described in Section 2). Finally, the MI starts gathering the BER information from the drop port receiving the L0 flow thanks to our OF Request message. The polling rate is dynamically adjusted by the MI depending on the BER value compared to the BER notification threshold. Moreover, we add another mechanism with lower priority to adjust the polling rate based on time derivative of BER (speed of variation). At the beginning the polling starts from a reasonably low rate (one request every 5 seconds).

Once the threshold is reached the QMA is notified by the controller and, as a consequence, the QMA requests the controller for signal spectrum information at the transmitter and receiver side, defined by the central frequencies (CF_{TX}, CF_{RX}) and the 3dB-bandwidths (B_{TX}, B_{RX}). The controller uses the values stored in the database for the transmitted spectrum information while it sends an OF message to the destination node for getting the received ones. The destination node uses the OSA to retrieve CF_{RX} and B_{RX}. The QMA, then, compares the values of central frequencies and, in case they differ, it computes a new central frequency (CF_{NEW}) for the transmitter and receiver according to the following formula: $CF_{NEW} = CF_{TX} + 2(CF_{RX} - CF_{TX})$. Finally, the controller reconfigures the new central frequency through OF.

4. Conclusion

We demonstrated a SDN-based QoT monitoring that automatically reconfigures any misalignment of central frequencies. We introduced OF protocol extensions to enrich the list of parameters but also to add new capabilities with instant values and statistics such as variance and minimum values. We developed a novel monitoring intent inside the controller to perform smart parameters retrieval by dynamically adapting the polling rate. Finally, we abstracted these functionalities through a generic notification mechanism to which the monitoring application can subscribe.

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