Situation-Aware Multipath Routing and Wavelength Re-assignment in a Unified Packet-Circuit OpenFlow Network

Weiyang Mo, Jun He, M. M. Karbassian, John Wissinger, and Nasser Peyghambarian
University of Arizona, College of Optical Sciences, 1630 E University Blvd., Tucson 85721, USA
{wmo, jhe, mkarbassian, jwissinger, nasser}@optics.arizona.edu

Abstract: We demonstrate multipath routing and wavelength re-assignment in OpenFlow-enabled packet-circuit network, aware of links’ bandwidth utilization, applications’ protocol, and quality of transmission. Applications are re-routed under traffic congestion and wavelengths are re-assigned under physical impairments.

OCIS codes (maximum 3): (060.4251) Networks, assignment and routing algorithms; (060.4253) Networks, circuit-switched; (060.4259) Networks, packet-switched;

I. Introduction

Nowadays, optical circuit networks and electronic packet networks start to converge under the new technologies, e.g. ROADM and software defined networking (SDN). This new trend is driven by the ever increasing bandwidth demand and new applications, such as mobile backhaul and huge data transfer inter/intra data centers. The convergences of optical circuit networks (i.e. transport network) and electronic packet networks (IP network) provide more capabilities that current networks do not have. For example, the optical network today remains largely static under the provider’s manual control, it takes days to set up/provision a new circuit/connection for customers. We demonstrate in this paper that the service provisioning time has been shortened to seconds in our converged packet-circuit network testbed.

To implement these new services and convergence, OpenFlow protocol, realizing software defined networking, is a promising solution compared with other technologies, such as GMPLS [1]. Generally, the SDN [2] technology separates the control and data planes so that researchers can introduce a new functionality by writing a software program that manipulates the logical map of the network. OpenFlow [2] is an open-source approach which aims at building up an SDN which provides networks with programmability of new functionalities. OpenFlow controllers manage OpenFlow-enabled network elements through OpenFlow protocol. The controller will have full access to all OpenFlow-enabled devices and thus collect statistics (e.g., ports’ packet counts, flow entry duration time).

Recently, several unified packet-circuit OpenFlow networks were demonstrated in [3, 4, 5] as proof-of-concept. In [3], the authors developed a centralized OpenFlow controller to manage circuit switches. In [4], OpenFlow controller is developed to manage photonic cross-connects (PXC) as OpenFlow-enabled optical nodes. In [5], the authors demonstrate a unified OpenFlow control plane and demonstrate application-aware traffic aggregation by using a centralized controller.

As validated by these recent results, unified packet-circuit OpenFlow network has significant benefits but there are still several important issues to be addressed. In dynamic optical networks, the physical impairments become major performance limitation because the pre-planning is not feasible for dynamic services. Consequently, a type of situation-awareness, called quality-of-transmission (QoT) awareness is required in unified packet-circuit OpenFlow network controller. Also, other types of situation-awareness, such as traffic congestion, links’ bandwidth utilization, and energy, are highly preferred. In this paper, we propose our extensions to OpenFlow by adding application-aware multipath routing function and QoT-aware wavelength re-assignment function.

Our algorithm can find out the link congestion and intelligently re-route a part of traffic to other paths based on the traffic protocol types and application requirement such as high-bandwidth, low-jitter and low-latency. Other than in traditional networks that have limited access for network operators under traffic congestion, this extension to OpenFlow can decide how to reorder the packets based on different traffic types, and even give specific traffic a secondary optimized route to ensure its quality of service. Additionally, any service interruption due to physical impairments from the optical lightpath will be detected in real time. Then our algorithm will re-assign the impacted traffic to another clean wavelength. The dynamic wavelength re-assignment in the experiments only takes few seconds compared to hours even days in current networks.

II. The Proposed Capabilities of Unified Packet-Circuit OpenFlow Network

Here, we develop a unified centralized controller with a few capabilities outlines as follow:
(i) **Unified packet-circuit OpenFlow network**: The unification with a centralized OpenFlow controller enhances the interaction between circuit and packet switched network. The controller monitors and collects the status of packet switches as well as optical nodes, and then dynamically configures the network if necessary (See Fig. 1).

(ii) **Application-aware multipath routing under traffic congestion**: Generally, OSPF paths with lowest latency are the best optimized ones for all traffic. However network will meet with traffic congestion when more traffic come that total traffic exceed the path bandwidth capacity and cause large packet loss. For different applications, they have different characteristics and thus different requirements. For example, the video streams have low-jitter requirement, and a high-data-rate IP traffic flow requires large bandwidth capacity that the congested path does not fit. In our demo, the controller gets the bandwidth utilization by calculating total bytes transferred per second, and is aware of application protocols. The high-data-rate IP traffic by IXIA traffic generator is dynamically re-routed to another path which goes through a circuit-link, thereby relieving the congestion in the packet-link and recovers the video stream.

(iii) **QoT-aware wavelength re-assignment under physical impairment**: In the unified packet-circuit network, the controller is also monitoring optical nodes and the optical to noise ratio (OSNR) in the physical layer. When the optical channel is interrupted by physical impairment or fiber cut, the controller detects the abnormality and manages optical nodes to assign a new clean wavelength channel to avoid packet loss for IXIA IP traffic.

### III. Situation-aware Multipath Routing and QoT-aware Wavelength Re-assignment Demonstration

The situation-awareness demonstrated here focuses on links’ bandwidth utilization, applications’ protocol, and QoT. This experiment is based on four Pronto 3290 packet switches, two Fujitsu FlashWave 9500 (FW) optical nodes, IXIA 1600T GE traffic generator (shown in Fig. 1). Each Pronto 3290 has four 10Gigabit (10G) optical ports. The FWs have 10GE interfaces connected to the Prontos’ 10GE ports, and SONET/SDH over WDM interfaces connected to one another as shown in Fig. 1. This network also includes a few end host PCs with various kinds of http, ftp and HD video stream generators, and another PC running the OpenFlow controller (POX [6]) in which our proposed capabilities are implemented.

In this demonstration, to emulate the traffic congestion, we configure the data-rate of different traffic to determine the congestion occurrence in the channel. As shown in Fig. 2(a), three different traffic types from the hosts/customers are aggregated into three bundles, then alongside the mixed traffic from other customers (i.e., IXIA) as in Fig. 2(b). The traffic include HD video stream which takes 5% usage of OSPF link’s bandwidth, 5% FTP downloading, 3% HTTP mixed with 90% IXIA IP traffic. Then the aggregated traffic (103% in total) gets routed through Pronto 3290’s GE default OSPF path where the actual measured maximum usage is ranging from 90% to 97%. As expected, the traffic congestion occurs, and causes packet loss and the video is seriously degraded.
In Fig. 2(a), the OpenFlow controller dynamically calculates OSPF path and forwards all traffic accordingly. In general, this OSPF path is the best optimized path for all traffic since it has lowest latency and no packet loss. In Fig. 2(b), we aggregate the 90% IXIA IP traffic from IXIA traffic generator to emulate the traffic congestion. This default path is no longer the best optimized path for IP or video streams. The video quality will be seriously degraded because of high-jitter due to the congestion. But for the IXIA IP traffic, low-latency is not as important as low packet loss and low-jitter is important as well as low-latency for video streams. The controller monitors bandwidth utilization status and application types, detects the congestion, and then dynamically sets up a secondary-optimized routing path (see in Fig. 2(b)) for IXIA IP traffic with high bandwidth capacity (i.e. through 10GE and 10Gbps WDM) but more latency due to longer route. IXIA IP traffic’s packet loss is eliminated and the video is recovered smoothly within few seconds.

We also demonstrate QoT awareness as shown in Fig. 2(c) and the optical performance monitoring (OPM) schematic is shown in Fig. 2(d). The controller gets the wavelength channel status through the OPM module. We demonstrate the QoT awareness by introducing ASE noise as physical impairment which causes OPM readings below certain OSNR and high packet loss for IXIA IP traffic. Then the controller dynamically configures the FWs to assign a new available wavelength to eliminate the packet loss within few seconds.

IV. Summary

Our research develops multipath routing under traffic congestion in a unified OpenFlow network. The network can be dynamically configured to satisfy requirements of different applications (e.g., eliminate packet loss for high-data rate IP transmission and jitter for video streams) within few seconds. The dynamically configured network improves the operation’s efficiency and customers’ quality of experience. We also develop QoT-awareness which can reduce the recovery time from a few hours (in current networks) to few seconds in circuit domain with OpenFlow. In the future, we plan to implement more capabilities like energy-awareness optimization with OpenFlow protocol to save energy consumption.

V. References