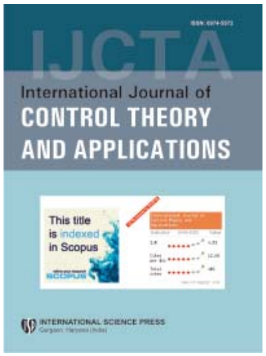

International Journal of Control Theory and Applications

ISSN : 0974–5572

Volume 9 • Number 40 • 2016

Simulation Study of Intent Based Path Computation in Software Defined Optical Network

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Abstract: The emerging software defined optical network is expected to offer high bandwidth and reliability in a cost-effective manner. One of the core problems in such software defined optical network is constraint based path computation in which various path computation algorithms relies on the optimizing different optimization criteria(s) of the paths. Hence there are different criteria(s) to be optimized with respect to every label switched paths, calculating the paths based on the intents negotiated by application is the common approach. In this paper, we have simulated the intent based establishment of label switched paths. An open network operating system (ONOS) based simulation of the intent based constrained path establishment for the software defined optical network was performed.

Keywords: *Optical networks, constrained path computation, QoS, Intent based path computation, ONOS.*

1. INTRODUCTION

In optical networks, the virtual topology is a set of optical channels called ‘light paths’ with traffic carried from source to destination. The collection of lightpaths which are satisfying or optimizing several QoS parameters will constitute the virtual topology (VT) [1] of the physical topology. Such virtual topology design must exploit the best of optical switching and routing abilities. Before the data is converted to the optical medium, the logical topology /virtual topology of the underlying physical topology has to be identified by solving routing and wavelength assignment sub problem effectively. The algorithmic complexity of finding such light paths is NP hard, as the performance of the algorithm greatly relies on the ongoing traffic status of the network. Hence with the exact algorithms or appropriate heuristics the light paths can be found with acceptable level of optimization.

As the provisioning and maintenance of these optical networks has become quite complex, the software defined networking (SDN) approach [2] was highly preferred. The intelligence of choosing the appropriate algorithms can be automated with the novel SDN mechanism. In this work the simulation of the ONOS controller and the PCE based path computation was performed.

The following sections are organized as follows: In section.2, the problem of path provisioning in optical network is discussed along with the major existing approaches. The section.2 also discusses the possibilities of software defined and intent based path computation in optical networks. The section.3 briefs about the experimental setup made to simulate the intent based path provisioning.

2. PATH PROVISIONING IN OPTICAL NETWORKS

2.1. Major Approaches

There are four major aspects in establishing the optical path between the source and destination points [3]. They are as follows:

1. Topology discovery and management
2. Lightpath routing
3. Wavelength assignment
4. Traffic routing and management.

There are many heuristic algorithms available in literatures to solve the RWA problem in a meaningful time. But none of the algorithms simultaneously considering all the QoS parameters, but relies on improving some parameters separately. The RWA problem consists of two sub problems namely routing and wavelength assignment.

The degrading effects of various physical layer impairments [4] must be accounted in RWA. The various undesirable effects of physical layers can be avoided by intelligent wavelength assignment techniques.

The important parameters which decide the various impairments are namely power and dispersion. Apart from light path routing, the path computation algorithm can also find best locations for electronic conversions, so as to minimize the nonlinear effects.

The route can be optimally partitioned into the minimum number of transparent segments by introducing a new segment when the accumulated impairment exceeds the acceptable threshold. Hence in this way there are different approaches available to solve the problem of RWA. The ability of different RWA approaches in finding the paths with various optimization levels was elaborated. The importance of accounting the physical layer impairments for the path computation and the need of impairment aware RWA was also discussed.

1.2. SDN Based Path Provisioning

The emerging network based applications are demanding high bandwidth and improved flexibility from the network providers. The SDN based server virtualization [5] gives rise to the flexible configuration of the networks, with its cloud based orchestration or its load balancing abilities. The five basic attributes of the SDN are namely, separation of planes, centralized controller, network automation, virtualization, network openness. The applications which use SDN controllers as a main component are enterprise network applications, data center network applications and core backbone network applications and so on. The SDN can be exploited for the rapid provisioning of the dynamically changing network requirements in-terms of QoS and other constraints like security etc. The existing network infrastructures may take more processing time in meeting those requirements for every single traffic flows. The SDN separates and abstracts the control plane of the existing network elements and keep the control plane in a central place. The control plane will communicate with the data plane through the southbound interface protocol. The data plane is responsible for the notification and transmission of data traffic whereas the control plane is responsible to control the traffic by following some policies inside the controller. The SDN applications can be implemented on top of the control plane which can be programmed using Northbound interfaces (NBI).

By sending the appropriate control messages the controller can add, update or delete entries in the forwarding table. In this way, the Openflow paths can be updated by the controller for even every frame or flow basis. The controller can change the network configuration to realize the new network path (flow) by appropriately modifying the forwarding table entries along the path. Hence the controller can derive the desired forwarding table by running the appropriate routing algorithm with the control plane. If the controller can able to run the appropriate path computation algorithm for each flow, it can serve the requests in an optimum level. The SDN controller contains the functional block called Path Computation Element (PCE) [6]. PCEP is the standard communication protocol used by PCE.

The PCE is responsible for computing the paths. This is also responsible for the provisioning and abstraction control. The PCE can be directly programmed using the SDN controller [7]. Initially the PCE will be in IDLE state inside the controller. When any PCC tries to communicate with PCE, OPEN_WAIT timer will get started and the PCC will be switched to OPEN_WAIT state. Before the open-wait timer expires, open-message will be sent by the PCE and the PCC will change its state to SEND_OPEN_MSG state. And the PCC will be changed to KEEP_WAIT state after starting up the keep-wait timer. Before the keep-alive timer expires, the PCE will send the keep-alive message after change its state to SEND_KEEP_ALIVE_MSG. If this message is caught successfully by PCC, the session will be established between PCC and PCE. Hence the PCE based SDN controller can provide the benefits such as visibility of network topology, programmable network state, network optimization and effective utilization of resources etc.

1.3. Intent Based Path Provisioning

The intent-based routing is not based on conventional way of networking which is telling what to do, but the idea is telling the network elements what the applications want. Some of the examples for intent are low latency, high speed, twenty megabits per second, high secure, best possible transport quality, constant bit rate etc. The desirable qualities of the intent are infrastructure agnostic, portable, compose-able. Since SDN can provide these qualities, the intent based routing is very much possible with use of the SDN. The SDN can convert the intents into the required set of actions (prescription). The prescription may involve finding a new OSPF path and updating all the switches involved in the path. The prescription may involve the critical interface between the cloud orchestration systems (ex: openstack) and SDN controllers. In this paper we propose the concept of matching the prescription of the intents with the criteria(s) of various path computation algorithms.

Normally the constraint based routing poses different bandwidth constraints according to the different classes of services and also optimizes the demanded TE-Metrices. The constraint based routing can rely on either the IGP's Metrics or TE metrics. The Interior Gateway (IGP) routing protocols (OSPF and IS-IS) and Generalized Multi Protocol Label Switching (GMPLS) signaling protocols (RSVP-TE and CR-LDP) have also been extended to support various functionalities required for traffic engineering (TE) [8]. But optimizing more than one TE metric is known to be NP-Hard. Hence the idea of establishing multiple LSP's each optimized according to the intents of the application is proposed. For the implementation of this proposal we have used PCE, SDN and ONOS.

3. SIMULATION OF INTENT BASED PATH PROVISIONING

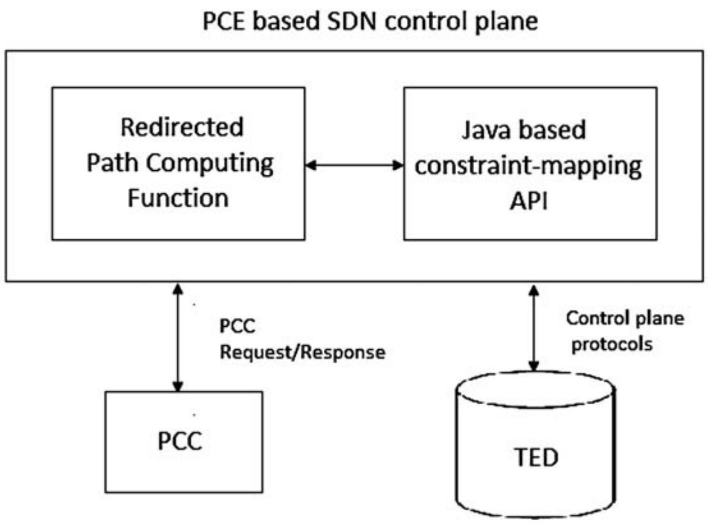
3.1. Simulation Setup

The ONOS optical network development environment was created by cloning the ONOS package. The various steps followed during the environmental setup are given below:

1. Download and install Oracle VirtualBox
2. Download Ubuntu 14.04 image file
3. Import Ubuntu image file into virtual box
4. Install Oracle JDK 8 and Mininet
5. Download ONOS package using git clone command from https://gerrit.onosproject.org/onos

3.2. Methodology

For the simulation of intent based path computation, we have used ONOS emulator. The open network foundation (ONF) is taking a major lead in developing the north bound application interfaces like openday light, ONOS etc. The ONF is also working on a intent- based routing approach. The open network operating system provides the control plane for the SDN to manage the network elements [9]. With ONOS the management and configuration of the network will become much easier. The ONOS is an opensource project which provides the platform to execute custom build software modules on top of the control plane for a particular SDN use case [10]. We have written the python scripts to simulate the required physical topology with fixed number of switches and hosts. The environment was set with BGP link state plugin to behave like a muli-domain system. Since in ONOS the default traffic flow is reactive, whenever a new traffic is encountered, it will be sent to controller and the controller will handle the unknown traffic. ONOS GUI was used to explore the optical network packet transmission. This web interface was used to find the instances of the controller, hosts, links and switches of the optical network and packet details. The architecture diagram of PCE communication given below in Figure 1.



Figur 1: Architecture diagram for proposed solution

The ONOS can consume the switch updates while finding the route between any two given hosts. The ONOS provides PCE and PCECC applications to enable the MPLS capability to the network [11][12]. With this application we have activated various LSP's (Label Switched Paths) each with different QoS requirements as per the intents of the applications. For every request the flow table details were fetched using the ONOS flow related commands [13][14]. The flow table for device 2 is given in Figure 2.

FLOW ID	APP ID	GROUP ID	PACKETS
0x10000087b9830	1	0x0	0
Criteria: ETH_TYPE:arp			
Treatment Instructions: OUTPUT:CONTROLLER			
0x1000064d9076a	1	0x0	0
Criteria: ETH_TYPE:bddp			
Treatment Instructions: OUTPUT:CONTROLLER			
0x10000685d7af8	1	0x0	16
Criteria: ETH_TYPE:arp			
Treatment Instructions: OUTPUT:CONTROLLER			

Figure 2: Flow table for Device 2

The PCE tunnels were created using various QoS requirements such as bandwidth, cost, congestion and delay. These requirements were activated through the Java programs by exploiting the API features of PCE and PCECC in ONOS. The format of the PCC request and response is given in Table 1 and Table 2.

Table 1
PCC Request Message

SVEC	RP	End Points	LSPA	Bandwidth	Metrics	PRO	IRO	Load Balancing

Table 2
PCC Response Message

RP	ERO	LSPA	Bandwidth	Metrics	IRS

We have observed the instances of the controller over a period of time. The details of hosts, links, switches and related details are observed for every LSP. The packet flow statistics were noted to analyze the throughput of LSP's. The packet flow details of device 2 is given in Figure 3.

PORT ID	PKTS RECEIVED	PKTS SENT	BYTES RECEIVED	BYTES SENT
1	40	17,945	2,880	2,041,777
2	0	13,362	0	1,106,204
3	0	13,365	0	1,106,498

Figure 3: Packet Flow details for Device 2

The throughput of LSP's are analyzed and represented in a form of graph as given in Figure 4 as follows:

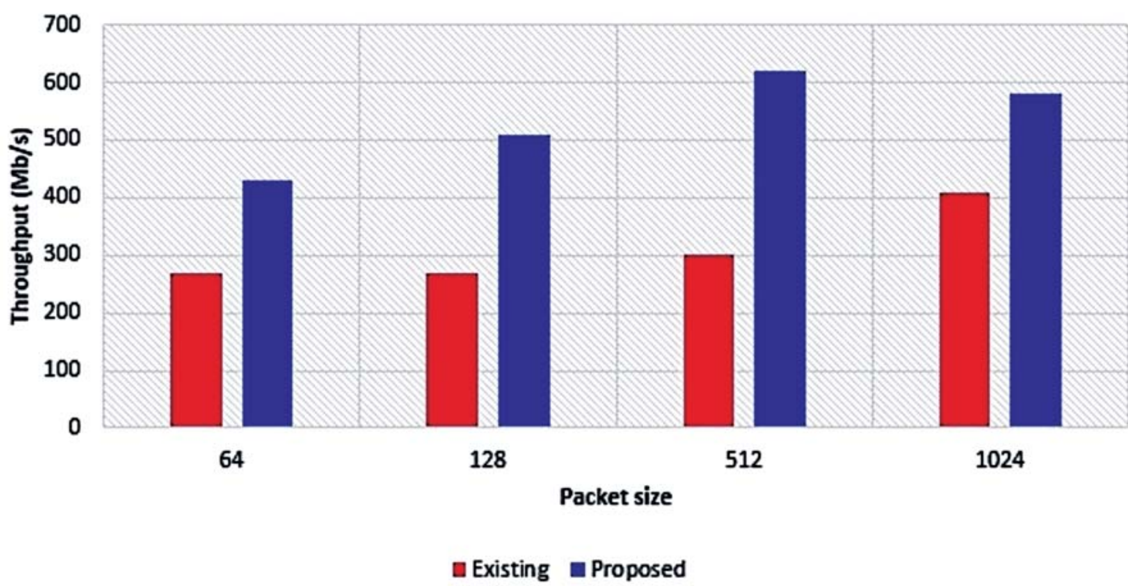


Figure 4: Throughput in terms of packet size

The various observations made with the LSP creation and updates are also tabulated as shown in the below table. The throughput (Mb/s) of all created LSP's are monitored. The tunnel details is given in Table 3.

Table 3
Tunnel Details as taken from ONOS Environment

Operation	*Source LSR-ID*	*Destination LSR-ID*	*Source Interface*	*Destination Interface*	*Tunnel ID*
Create	4.4.4.4	5.5.5.5	11.1.1.4	11.1.1.5	1234
Update	4.4.4.4	5.5.5.5	12.1.1.4	12.1.1.5	1234

Hence the simulation of intent based label switched path creation has been done in the ONOS environment and the various statistical details of the LSP's were observed to analyze the status of the network as well as the established LSP's.

The following steps were followed in ONOS environment, during the optical path computation:

1. Toggle the topology view in ONOS GUI Web Interface to the Packet layer.
2. By pressing the Shift and left mouse keys simultaneously, the Source and Destination hosts would be selected.
3. Set the constraints of the paths through ONOS Constraints Interface.
4. After the path has been computed by PCE, the tunnel from source to destination will be created and the same will be displayed in ONOS GUI Web Interface.
5. Once the tunnel is created the experiments with tunnel updation, deletion has been done.

The ONOS environment view of the custom made optical network topology is given in Figure 5.

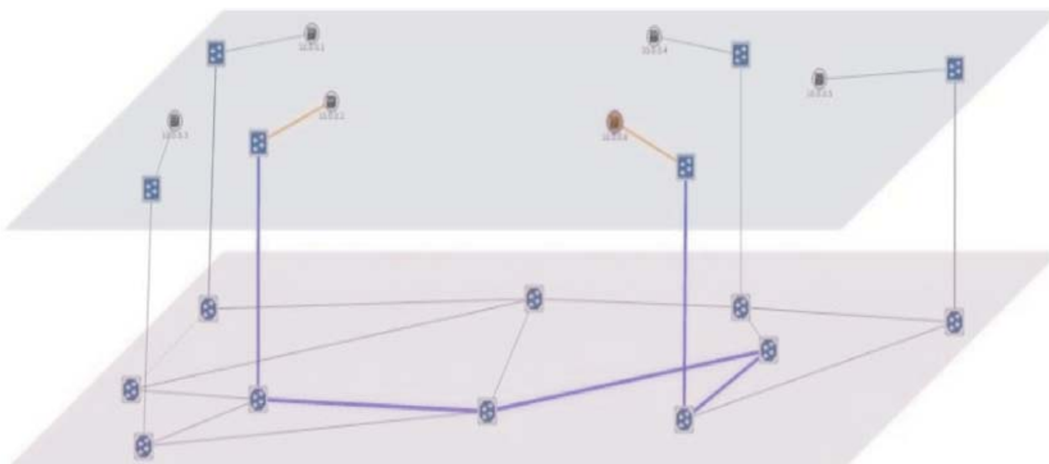


Figure 5: ONOS environment with custom made topology of packet and optical networks

4. CONCLUSION

In this paper we have proposed an intent based LSP creation with the various path evaluation criteria(s). We have written the java applications in ONOS environment, to add additional functionality with the PCE application to compute the LSP's with required Quality of Service (QoS). The simulation of the constrained LSP's was performed and the statistical details of every LSP was monitored. The various south bound and north bound API's ONOS was used to interface with PCE and optical routing and control plane protocols. Thus the possibility of establishing simultaneous LSP's with different levels of QoS was performed as a constrained path computation scenario of the software defined optical network.

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