University of Colorado
Interdisciplinary Telecommunications Program
TLEN 5700

Project Definition Document (PDD)

Software Defined Backbone (SD-Backbone)

Approvals

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Approved</th>
<th>Date</th>
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<tr>
<td>Customer</td>
<td>Prof. Jose Santos /</td>
<td>CU Boulder</td>
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<td></td>
<td>Dr. Levi Perigo</td>
<td>ITP</td>
<td></td>
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<tr>
<td>Course Coordinator</td>
<td>Dr. Kevin Gifford</td>
<td>CU Boulder</td>
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<td>ITP</td>
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Project Customers

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<tr>
<th>Name:</th>
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Team Members

<table>
<thead>
<tr>
<th>Name: Foram Shah</th>
<th>Phone: +1-(714)-949-9586</th>
<th>Email: <a href="mailto:foram.shah@colorado.edu">foram.shah@colorado.edu</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Rahul Sharma</td>
<td>Phone: +1-(720)-755-7813</td>
<td>Email: <a href="mailto:rahul.sharma@colorado.edu">rahul.sharma@colorado.edu</a></td>
</tr>
<tr>
<td>Name: Puneet Singh Sarna</td>
<td>Phone: +1-(720)-755-7803</td>
<td>Email: <a href="mailto:puneet.sarna@colorado.edu">puneet.sarna@colorado.edu</a></td>
</tr>
<tr>
<td>Name: Amogh Morye</td>
<td>Phone: +1-(720)-755-7814</td>
<td>Email: <a href="mailto:amogh.morye@colorado.edu">amogh.morye@colorado.edu</a></td>
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1.0 Problem or Need

This project aims to improve existing implementation of Multiprotocol Label Switching Resource Reservation Protocol-Traffic Engineering (MPLS RSVP-TE) in Internet Service Provider (ISP) networks by creating a Software Defined Backbone (SD-Backbone), which leverages the use of a Software Defined Networking (SDN) controller along with policy-based routing/explicit route path/as per the method compatible with the devices provided by our sponsor/industry advisor (Arista Networks, Inc.).

The Internet Service Provider (ISP) is primarily responsible for providing internet service to its customers [1]. The ISPs are gatekeepers of the Internet, and this puts the ISPs in a very challenging role. With an aim to provide consistent, high-quality internet service to its customers and to utilize its networking resources efficiently for generating a sufficient revenue for its stakeholders, the ISPs are constantly adopting new technologies [1].

The idea behind the project is to harness the features of MPLS RSVP-TE i.e., resilience, flexibility, and simplicity and combining it with a centralized global approach to easily create end-to-end connectivity utilizing the best available resources in the network. The operation of the project can be explained in two simple words: compute i.e. compute the best path for the packet flow through the backbone network and set-up i.e. set up the path in the backbone network for packet flow [2].

The project will help the ISPs to quickly adapt to the traffic changes in the network with the help of the centralized controller which makes all the information available at one single node for best path computation. The project will save time and effort of the network managers as no manual configuration of the best path using Command Line Interface (CLI) will be required as per traffic changes. The centralized controller will perform all the complex computation without any human intervention.

2.0 Previous Work

It started with Interior Gateway Protocol (IGP) metric controlled dedicated lines, which was succeeded by ATM, providing logical end-to-end connections with Private Virtual Circuits (PVCs). Then came the MPLS technology which overcame the disadvantages of its predecessors by providing a unified service for all kinds of traffic such as voice, video, data, and other services [3]. MPLS routers apply numerical labels to the packets and make a forwarding decision based on the same. The provider edge routers are called as LERs (Label Edge Routers), where the label is pushed onto the packet at ingress and popped out of the packet at egress. The routers within the network, switch the labels, i.e. pop-out the incoming label and push-in a new routing label, hence, are called LSR (Label Switched Routers), and the path taken by the packets inside the network is called LSP (Label Switched Path) [4].

MPLS along with RSVP-TE provides several advantages [5]. The path calculated by an IGP using the Shortest Path First (SPF) algorithm is not always the best path, as it might be congested. RSVP-TE provides additional constraints to the path selection criteria i.e. bandwidth [5]. This is called as CSPF (Constrained Shortest Path First). CSPF ensures that the traffic uses uncongested path with some latency rather than the congested shortest path [5], as the bandwidth can be reserved at each node in the network. However, as the networks get complex, defining constraints at each node in the network becomes difficult [6]. Moreover, it also suffers from scalability issues such as, a limited number of LSPs can be established within the network and separate information that needs to be maintained for upstream and downstream paths [6].

Unlike MPLS RSVP-TE wherein each node is required to maintain the state of LSPs, an algorithm will be developed and placed inside the controller which will continuously build a dataset by collecting real-time values of the pre-defined parameters from each node which is part of the MPLS backbone network,
thereby making all the information available at one single point. Based on the gathered parameters, the controller will determine the path for each incoming packet before entering the backbone network.

The problem and solution presented above require a thorough understanding of the present MPLS backbone network and its deficiencies, and the configuration and implementation of SDN. The IEEE paper [7], the RFC 6882 [8], and the RFC 3210 [6] provides a good foundation regarding the project. The IEEE paper [4] highlights various SDN controller implementations which can be used in Wide Area Network (WAN), where they have highlighted the use of NETCONF, CLI, and PCEP to realize dynamic tunnels.

Additionally, the RFC 5439 [9] and the capstone project “Evaluating performance on an IP MPLS Network” from 2010 [10] provides an insight into MPLS RSVP-TE practical implications in an ISP backbone network. Further, the documents [11], [12], and [13] are the stepping stones as these provide the necessary theoretical explanation regarding the different protocols to be used in the project.

3.0 Specific Objectives

Level 1:
To build an IP-MPLS backbone with RSVP-TE (Resource Reservation Protocol-Traffic Engineering) in a lab environment with IS-IS (Intermediate System-Intermediate System) acting as the underlying IGP and BGP (Border Gateway Protocol) protocol implemented between the Provider Edge (PE) routers. The configuration, deployment, and testing for this stage will be done in the Telecom Systems Lab at the University of Colorado Boulder (TEL lab).

Level 2:
Identify the critical parameters such as link utilization, bandwidth, traffic patterns, latency, and link congestion from the above configuration that will be part of a dataset. This dataset will be the basis of the algorithm for the controller, to be developed in the succeeding levels. Additionally, identify the limitations and loopholes of the network developed in level 1.

Level 3:
Develop an algorithm, utilizing the above dataset, that will run on the controller to implement the functionality of a Software Defined Backbone. The centralized controller will gather the critical parameters and identify the best path for a packet inside the backbone network, which as mentioned previously will be in the form of the label stack. The forwarding method (TBD) i.e. policy based routing/explicit route/as supported by the hardware provided by our sponsor/industry advisor will guide the flow of the packet inside the backbone network. The configuration, deployment, and testing for this stage shall be done on the resources provided by the sponsor/industry advisor. The resources could be onsite in the TEL lab or at a remote location.

3.0 Functional Requirements

- The configuration of IS-IS (Intermediate System-Intermediate System) as the underlying IGP in the MPLS backbone and using a custom controller to determine a suitable forwarding path for an incoming packet.
- The controller takes input from IS-IS LSDB (Link State Database) and considers the critical parameters defined above to perform best path computation.
- The best path is computed and its configuration in the backbone network will be done by the controller.
5.0 Critical Project Elements

5.1. Researching the limitations of current MPLS implementation and identify the elements of the dataset:
Construct a small-scale backbone network, in a lab environment, which runs MPLS in its core with RSVP-TE and identify the critical parameters that will become part of the dataset for the algorithm on the controller. Determine the limitations of the constructed backbone network i.e. MPLS RSVP-TE.

5.2. Finalizing a method to push the commands and pull the critical parameters from the backbone network:
Establish communication between the controller and the devices in the backbone network and finalize a method to communicate with the network to build the dataset for the algorithm.

5.3. Dataset Creation:
Building the dataset on the controller containing the critical parameters identified in 5.1 and determine if the dataset is sufficient to calculate the best path. In case if the dataset is insufficient, identify and include the additional parameters in the dataset for calculating the best path.

5.4. The algorithm to compute the best forwarding path:
Create an algorithm which will utilize the above dataset to identify the best path through the network. The algorithm will use the created dataset, based on real-time network statistics, to compute the best path for the incoming packet at the PE routers.
6.0 Team Skills and Interests

**Rahul:** Rahul interned at Charter Communications in Summer’17 as Core IP Operations Intern and developed a tool to automate MOP (Method of Procedure). He has strong 2+ years of industry experience, holding both technical and managerial positions. His strength is his ability to integrate technology with business aspect. He is skilled in Routing, Switching, Python Programming, Software-defined technologies, and Linux system administration. He holds professional certifications in both traditional and software-defined networking. He is interested in design, algorithm development, comparative analysis, and testing aspects of the project.

**Amogh:** Amogh is a Master's student in the Telecom Program with focus on Network Engineering. He has experience with developing SDN controllers and Network Automation Scripts using Python. Having done projects with Machine Learning and Natural Language Processing, he has a knack for software development as well. He is interested in the algorithm generation and other software automation aspects of the project.

**Puneet:** Puneet interned with the National Backbone team of Charter Communications in Summer’17 which included tasks like scripting and automating the router’s pre/post checks during upgrades, designing a tool to automate Method of Procedure (MOP), and writing a script that generated updated network maps for the backbone network. He has one year of professional experience as an Assistant System Engineer under the Networks and Operations team at TCS. He has a good experience in Python programming, routing, switching, network monitoring and troubleshooting, and software-defined networks, and is highly interested in network automation.

**Foram:** She is presently working part-time at UCAR with their Network Engineering and Telecommunications Section (NETS) with a focus on network management related work. She did her internship at Red Hat Inc. in Summer’17. During the internship, she explicitly worked on Network Automation projects involving python scripting. She also has a practical experience in configuration of routers, switches, and other networking gear in a lab environment including implementation of several protocols.

7.0 Resources

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<tr>
<th>Critical Project Elements</th>
<th>Resource/Source</th>
<th>Expert/Technical Consultant</th>
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<tbody>
<tr>
<td>5.1. Researching the limitations of current MPLS implementation and identify the elements of the dataset</td>
<td>Hardware available in the TEL lab</td>
<td>Prof. Jose Santos and Technical Advisor (Arista)</td>
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<td>5.2. Finalizing a method to push the commands and pull the critical parameters from the backbone network</td>
<td>Hardware available from sponsor/industry advisor (Arista Networks, Inc.) using VPN access,</td>
<td>Prof. Jose Santos, Dr. Levi Perigo, and Technical Advisor (Arista)</td>
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<td>5.3. Dataset Creation</td>
<td>Hardware available from sponsor/industry advisor (Arista Networks, Inc.) using VPN access</td>
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8.0 References


APPENDIX:

Requirements and Constraints:

1. The traditional network setup established in the lab environment and must demonstrate the limitations of MPLS RSVP-TE implementation in the ISP backbone network.

2. The limitations identified should be vendor neutral.

3. The devices used in the traditional network i.e. devices in the TEL Lab must support automation and should be able to communicate with the controller only then the dataset can be computed by the controller.

4. Access to the devices i.e. either physical access in the TEL lab or remote access to the devices should be provided by our sponsor/industry advisor (Arista Networks, Inc.).

5. The packet forwarding method should be supported by the sponsor’s hardware.

Design Drivers:

Design Driver #1: All the libraries used for the software component of the project must be open source and replicable without incurring any licensing costs.

Design Driver #2: The new proposed backbone implementation should be able to overcome as many deficiencies as possible of the current one.

Design Driver #3: All the software designed must be completely compatible with the sponsor’s hardware.