Implementation and Evaluation of Routing Algorithm in GENI Software-Defined Networking

Wei-Hen Hsu

June 6, 2018

Contents

Chapter 1

Introduction

Software-defined networking (SDN) has received a lot of attention in recent years, several routing algorithms have been proposed by researchers. The environment that evaluates a routing algorithm is quite importmant.

Commonly, building up a SDN environment with real OpenFlow switches for evaluating the porformance of routing algorithms is very persuasive. Unfortunately, a real OpenFlow switch is expensive. It's costly to build a small-scale netwrok with real OpenFlow switches.

Another tool for building the SDN environment is the network testbed. The network testbed is a platform to provide network researchers with a realistic environment for testing. In some network testbeds, they are supported by governmentsit and it's free for researchers to use the testbed. Compared with previous ways, it is more cost-effective for researchers to build the environment.

Therefore, in this thesis, we propsed a method to implement the routing algorithms in **Global Environment for Network Innovations (GENI)** SDN testbed. The routing algorithms fall into the following two main categories: (a) online routing algorithm; (b) offline routing algorithm. In each catergory, we describe the process of creating a SDN on GENI and implementing the rouing algorithm on SDN.

Chapter 2

General Background Information

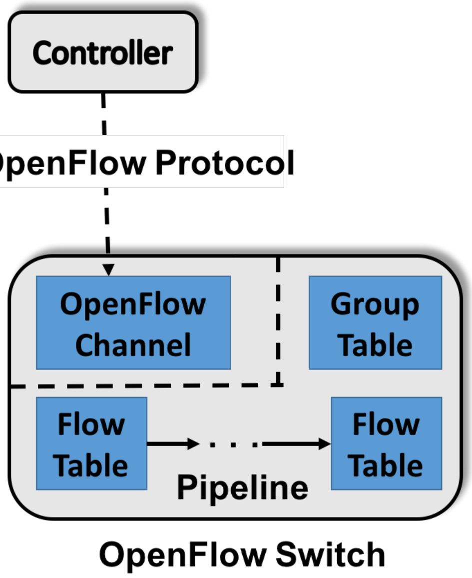
2.1 Software-defined networking

According to **ONF(Open Networking Foundation)** definition of software-defined networking, SDN is an architecture that is dynamic, manageable, cost-effective, and adaptable, making it ideal for the high-bandwidth, dynamic nature of todays applications. In traditional network, each network device usually has its own control plane. The transport of the packet is processed by network device individually. The SDN decouples the forwarding and control planes, removes the control plane from network device and implements it in sofware instead. The SDN enables the control plane to beccome directly programmable and the underlying infrastructure to be abstracted for applications and network services. The OpenFlow protocol is a foundational element for building SDN solutions.

2.2 OpenFlow

OpenFlow is a communications protocol between SDN controller and OpenFlow switch that enables the SDN controller to direct interact with the forwarding plane of network devices such as switches and routers. Figure 2.1 shows the main components of an OpenFlow switch.

Figure 2.1: Main components of an OpenFlow switch.



Match Fields	Priority	Counter	Instructions	Timeouts	Cookie

Table 2.1: Main components of a flow entry in a flow table

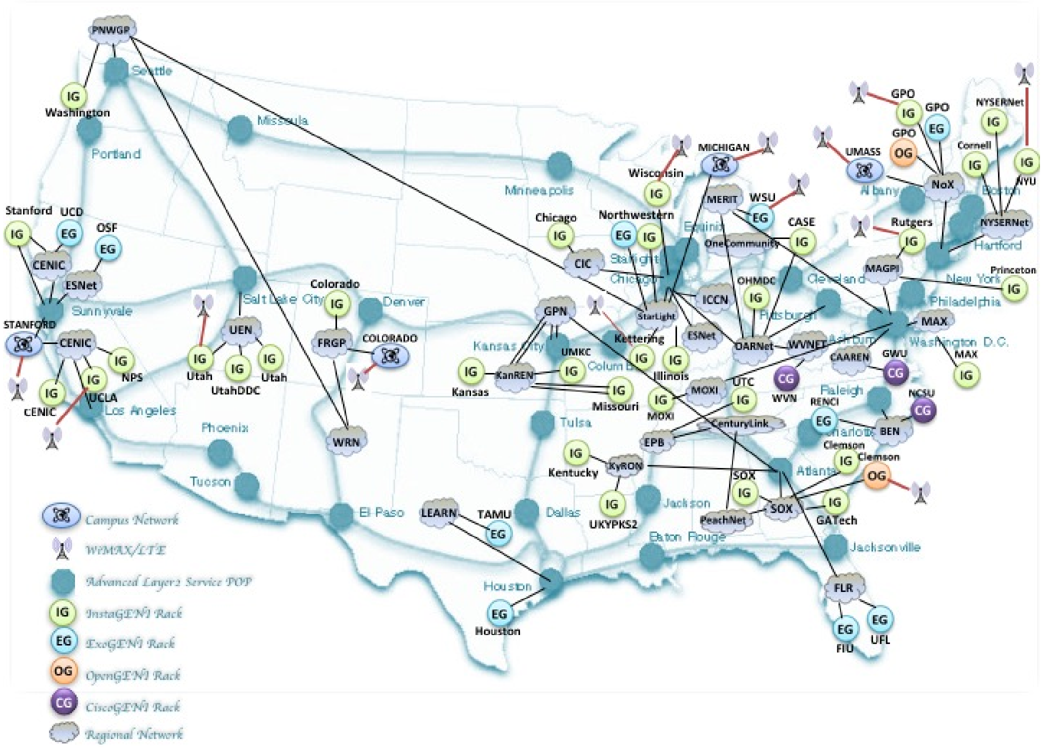
2.2.1 OpenFlow switch components

An OpenFlow switch consists one or more flow tables, which perform packet lookups and forwarding. The controller could use the OpenFlow protocol to add, update, and delete flow entries in flow tables. In each flow table, it contains a set of flow entries; each flow entry consists of match fields, counters, and a set of instructions to apply to matching packets. (see Table 2.1)

2.3 GENI

GENI provides a virtual laboratory for networking and distributed systems research and education.Researcher could obtain compute resources from locations around the United States. Figure 2.2 show the map of GENI compute and netwrok resouces. GENI allows user to install custom software or even custom operating systems on compute resources. Furthermore, researcher could control how network switches in their experiment handle traffic flows. GENI is sponsored by the U.S. National Science Foundation (NSF). If the researchers' institution belongs to an identity federation, the researchers are able to log in using their usual username and password. If their institution does not belong, they could apply for an account at the NCSA identity Provider.

Figure 2.2: The map of GENI compute and netwrok resouces.



2.4 Open vSwitch

2.5 Ryu controller

Ryu is a component-based SDN framework. Ryu is fully written in Python and provides software components with well defined API that make it easy for developers to create new management and control applications. Figures 2.3 shows the model of Ryu application. The data path thread will collect all the events from OpenFlow switch and dispatch the events to the event handler to process it. The programmer should define the event handler how to process the event. Figure 2.4 shows the status of ryu from the beginning till the end.

Figure 2.3: Ryu application programming model.

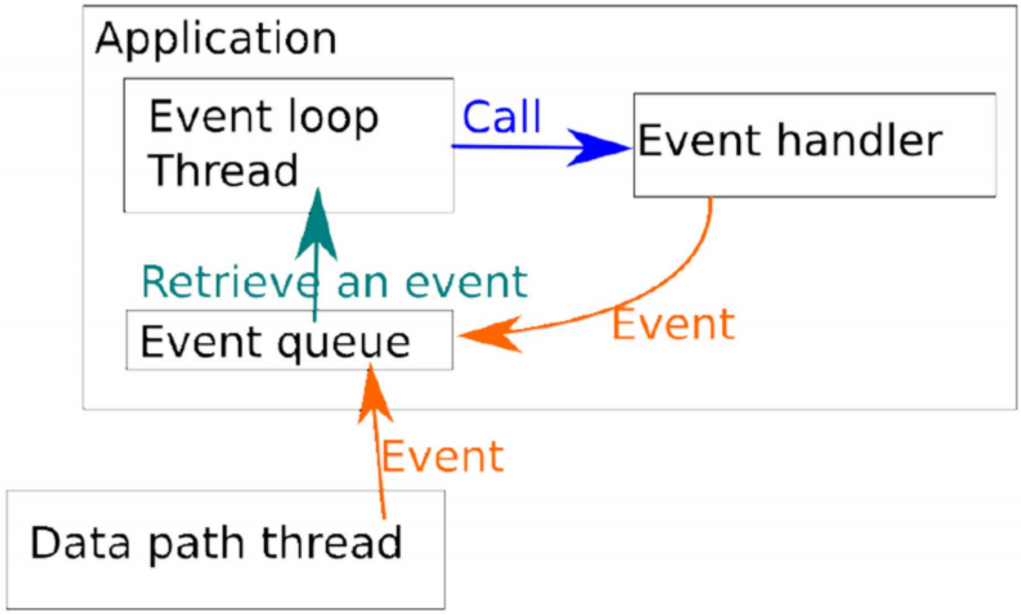
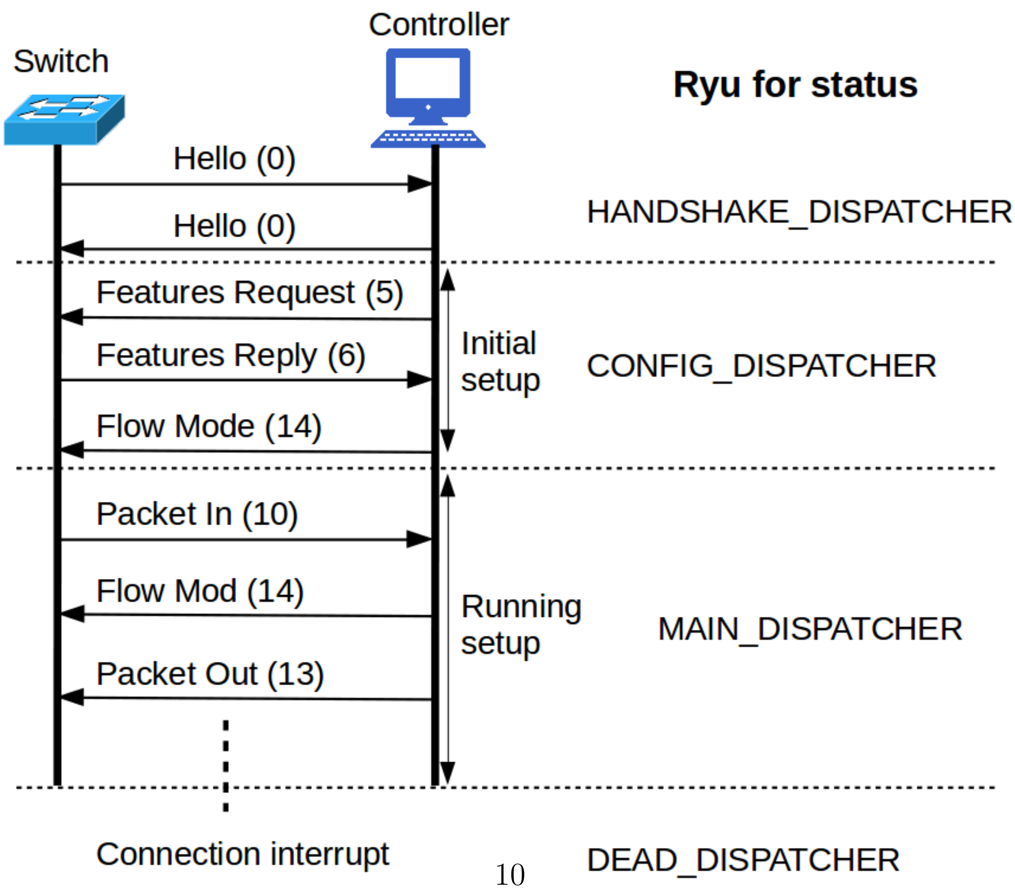


Figure 2.4: The four status in ryu controller



Chapter 3

System model

3.1 GENI model

Chapter 4

Implementation of Routing Algorithm in GENI

4.1 The reservation of compute resources for customized topology

In GENI, There are three methods to reserve the resources: (a) setting the topology manually; (b) choose existing topology; (c) import Resouce specification (Rspec) documents. Figure 4.1 to Figure 4.3 show the three methdos to reserve the resources. In (a), you could just drag the components into the screen and create the topology you desire. In (b) choosing the existing topology that the geni offering. In (c) To use the Rspec documents, you could write a program to output the Rspec document by following the Rspec structure.

Figure 4.1: (a) Setting the topology manually.

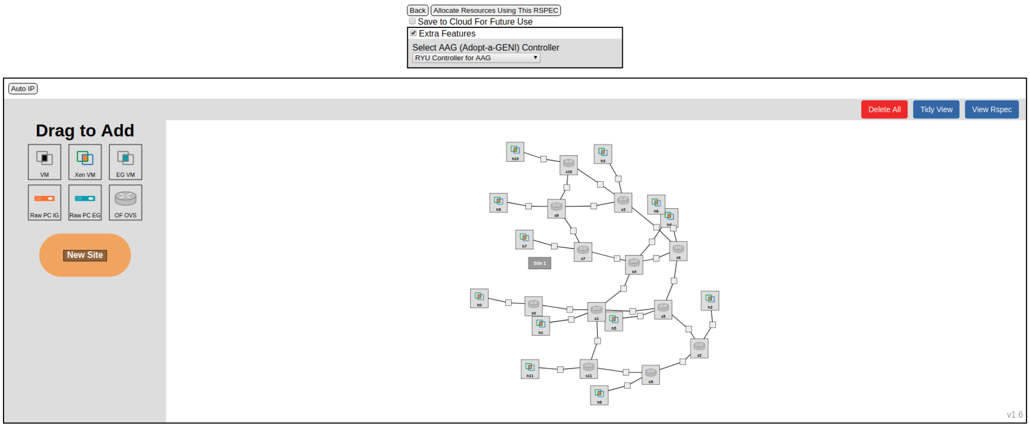


Figure 4.2: (b) Choose existing topology.

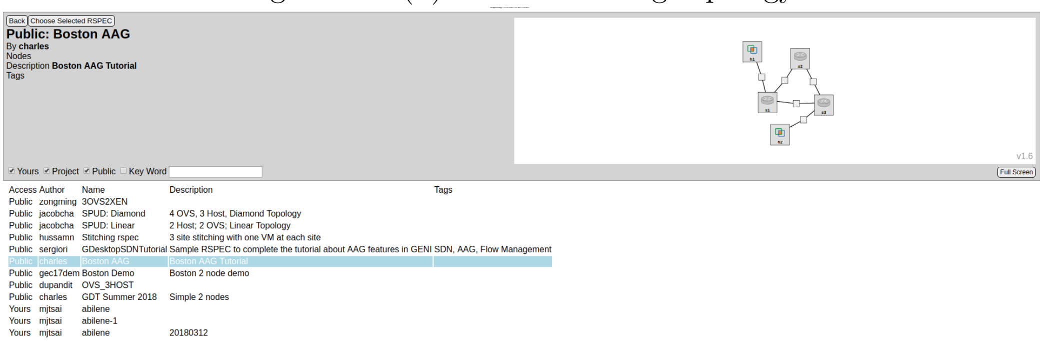
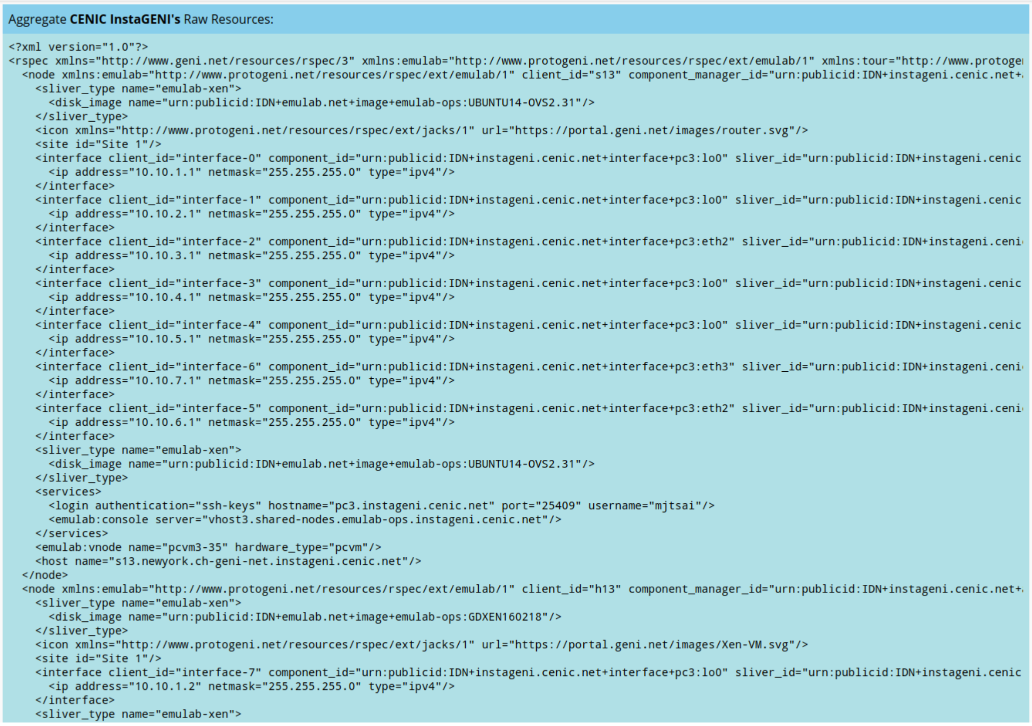


Figure 4.3: (c) Import Resouce specification (Rspec) documents.

```
-<rspec>
  -<node client_id="s2">
    +<sliver_type name="emulab-xen"></sliver_type>
     <icon url="https://portal.geni.net/images/router.svg"/>
     <site id="Site 1"/>
     <interface client_id="interface-0"/>
     <interface client_id="interface-1"/>
     <interface client_id="interface-2"/>
   </node>
  +<node client_id="s4"></node>
  +<node client_id="h7"></node>
  +<node client_id="h11"></node>
  +<node client_id="h9"></node>
  +<node client_id="h10"></node>
  +<node client_id="h5"></node>
  +<node client_id="h0"></node>
  +<node client_id="h8"></node>
  +<node client_id="h1"></node>
  +<node client_id="s5"></node>
  +<node client_id="s9"></node>
  +<node client_id="s10"></node>
  +<node client_id="s0"></node>
  +<node client_id="h4"></node>
  +<node client_id="s1"></node>
  +<node client_id="h3"></node>
  +<node client_id="s6"></node>
  +<node client_id="h2"></node>
  +<node client_id="s3"></node>
  +<node client_id="s11"></node>
  +<node client_id="s7"></node>
  +<node client_id="s8"></node>
  +<node client_id="h6"></node>
  -<link client_id="link-0">
     <interface_ref client_id="interface-0"/>
     <interface_ref client_id="interface-16"/>
     <property capacity="100000" dest_id="interface-16" source_id="interface-0"/>
```

Figure 4.4: The network structure in GENI



Aggregate **CENIC InstaGENI's** Raw Resources:


```xml
<?xml version="1.0"?>
<rspec xmlns="http://www.geni.net/resources/rspec/3" xmlns:emulab="http://www.protogeni.net/resources/rspec/ext/emulab/1" xmlns:tour="http://www.protoge
  <node xmlns:emulab="http://www.protogeni.net/resources/rspec/ext/emulab/1" client_id="s13" component_manager_id="urn:publicid:IDN+instageni.cenic.net+
    <sliver_type name="emulab-xen">
      <disk_image name="urn:publicid:IDN+emulab.net+image+emulab-ops:UBUNTU14-OVS2.31"/>
    </sliver_type>
    <icon xmlns="http://www.protogeni.net/resources/rspec/ext/jacks/1" url="https://portal.geni.net/images/router.svg"/>
    <site id="Site 1"/>
    <interface client_id="interface-0" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:lo0" sliver_id="urn:publicid:IDN+instageni.cenic
      <ip address="10.10.1.1" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <interface client_id="interface-1" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:lo0" sliver_id="urn:publicid:IDN+instageni.cenic
      <ip address="10.10.2.1" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <interface client_id="interface-2" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:eth2" sliver_id="urn:publicid:IDN+instageni.ceni
      <ip address="10.10.3.1" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <interface client_id="interface-3" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:lo0" sliver_id="urn:publicid:IDN+instageni.cenic
      <ip address="10.10.4.1" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <interface client_id="interface-4" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:lo0" sliver_id="urn:publicid:IDN+instageni.cenic
      <ip address="10.10.5.1" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <interface client_id="interface-6" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:eth3" sliver_id="urn:publicid:IDN+instageni.ceni
      <ip address="10.10.7.1" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <interface client_id="interface-5" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:eth2" sliver_id="urn:publicid:IDN+instageni.ceni
      <ip address="10.10.6.1" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <sliver_type name="emulab-xen">
      <disk_image name="urn:publicid:IDN+emulab.net+image+emulab-ops:UBUNTU14-OVS2.31"/>
    </sliver_type>
    <services>
      <login authentication="ssh-keys" hostname="pc3.instageni.cenic.net" port="25409" username="mjtsai"/>
      <emulab:console server="vhost3.shared-nodes.emulab-ops.instageni.cenic.net"/>
    </services>
    <emulab:vnode name="pcvm3-35" hardware_type="pcvm"/>
    <host name="s13.newyork.ch-geni-net.instageni.cenic.net"/>
  </node>
  <node xmlns:emulab="http://www.protogeni.net/resources/rspec/ext/emulab/1" client_id="h13" component_manager_id="urn:publicid:IDN+instageni.cenic.net+
    <sliver_type name="emulab-xen">
      <disk_image name="urn:publicid:IDN+emulab.net+image+emulab-ops:GDXEN160218"/>
    </sliver_type>
    <icon xmlns="http://www.protogeni.net/resources/rspec/ext/jacks/1" url="https://portal.geni.net/images/Xen-VM.svg"/>
    <site id="Site 1"/>
    <interface client_id="interface-7" component_id="urn:publicid:IDN+instageni.cenic.net+interface+pc3:lo0" sliver_id="urn:publicid:IDN+instageni.cenic
      <ip address="10.10.1.2" netmask="255.255.255.0" type="ipv4"/>
    </interface>
    <sliver_type name="emulab-xen">
```


4.2 Offline algorithm

4.2.1 create the network graph for the input of routing algorithm

After reserve the resources, copy the network structure document from GENI online website. Fugure 4.4 shows the the network structure document. The network structure document contains the information of nodes and links. Using this document to create the netowrk graph for the input of the routing algorithm.

4.2.2 setting up the demands

After the routing algorithm compute the pathes of the demands. In order to let the Open vSwitch to identify each demands, we use ip of source, ip of destination, port of destination to identify each demands. For each nodes, we create a script to run the demands with given information.

4.2.3 setting up the controller

For controller, we create a dictionary for it. Every time when a node asks the controller how to process the demands, controller could use ip of source, ip of destination, port of destination as a key to find the path of the demand then send the OpenFlow message to the switch for adding the flow into the flow table.

4.3 Online algorithm

4.3.1 ryu controller

In ryu controller, we need to implement a topology discovery which the routing algorithm could use. Figure 4.5 is the package which the Ryu controller need to import. Figure 4.6 is the code to discover topology.

Figure 4.5: Ryu controller import package for topology discovery.

```
from ryu.topology import event, switches
from ryu.topology.api import get_switch, get_link
```

Figure 4.6: The code of topology discovery in Ryu controller.

```
@set_ev_cls(event.EventSwitchEnter)
    def get_topology_data(self, ev):
    switch_list = get_switch(self.topology_api_app, None)
    switches=[switch.dp.id for switch in switch_list]
    links_list = get_link(self.topology_api_app, None)
    links=[(link.src.dpid,link.dst.dpid,{'port':link.src.port_no})
for link in links_list]
```