VIDEO STREAMING USING SOFTWARE DEFINED NETWORKING

MINOR PROJECT

Submitted by
SIDDHARTH MALHOTRA (9917103050)
HARSHWARDHAN SINGH KARKI (9917103037)
CHANDRAGUPTA MISHRA (9917103048)
PRAKASH KUMAR (9917103049)

Under the supervision of
Mr. NITIN SHUKLA

Department of CSE/IT
Jaypee Institute of Information Technology University, Noida

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Signature(s) of Students

Siddharth Malhotra (991703050)

Harshwardhan Singh Karki (9917103037)

Chandragupta Mishra (9917103048)

Prakash Kumar (9917103049)

ABSTRACT

The growing demand for online distribution of high quality and high throughput content is dominating today's Internet infrastructure. This includes both production and user-generated media

Enterprises, carriers, and service providers are being surrounded by a number of competing forces. The monumental growth in multimedia content, the explosion of cloud computing, the impact of increasing mobile usage, and continuing business pressures to reduce costs while revenues remain flat are all converging to wreak havoc on traditional business models.

Cloud computing creates dynamic capacities when required without setting up additional hardware. There in comes the role of big giant networks which need to be handled carefully

To keep pace, many of these players are turning to SDN technology to revolutionize network design and operations.

SDN enables the programming of network behaviour in a centrally controlled manner through software applications using open APIs. By opening up traditionally closed network platforms and implementing a common SDN control layer, operators can manage the entire network and its devices consistently, regardless of the complexity of the underlying network technology.

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ABBREVIATIONS AND NOMENCLATURE

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SDN: Software Defined Networking

ERNET: Education and Research Network

ONF: Open Networking Foundation

ICT: Information communication and technologies

LIST OF TABLES AND FIGURES

CHAPTER 1: INTRODUCTION

Emerging mega-trends (e.g., mobile, social, cloud, and big data) in information and communication technologies(ICT) are commanding new challenges to future Internet, for which ubiquitous accessibility, high bandwidth, and dynamic management are crucial. However, traditional approaches based on manual configuration of proprietary devices are cumbersome and error-prone, and they cannot fully utilize the capability of physical network infrastructure. Recently, software-defined networking(SDN) has been touted as one of the most promising solutions for future Internet. SDN is characterized by its two distinguished features, including decoupling the control plane from the data plane and providing programmability for network application development. As a result, SDN is positioned to provide more efficient configuration, better performance, and higher flexibility to accommodate innovative network designs.

1.1 : Software Defined Networking

The Open Networking Foundation (ONF) is a non-profit consortium dedicated to development, standardization ,and commercialization of SDN. ONF has provided the most explicit and well received definition of SDN as follows: Software Defined Networking (SDN) is an emerging network architecture where network control is decoupled from forwarding and is directly programmable As per this definition, SDN is defined by two characteristics, namely decoupling of control and data planes, and programmability on the control plane. Nevertheless, neither of these two signatures of SDN is totally new in network architecture, as detailed in the following

.First, several previous efforts have been made to promote network programmability. One example is the concept of active networking that attempts to control a network in a real-time manner using software.

1.2 : Implementation of Simplified Custom Topology Framework in Mininet:

Nowadays computer networks are in constant evolution and require scalability and programmability to be ready for innovations of next generation networks. Existing operational networks does not facilitate testing of new innovative ideas and protocols. Thus, there is a need to have test-beds that facilitate new innovation and new protocol experimentation, and a virtual network infrastructure fills that need. Virtualization is an act of creating a virtual version of something. It could be hardware virtualization, platform virtualization, server virtualization or network virtualization. Mininet is a virtual network test-bed that helps the researchers who would like to innovate and students who would like to understand the working of computer networks. Mininet mainly gains importance in the study and implementation of Software Defined Network

1.3 : Video Streaming using Software Defined Networking:

Supporting end-to-end quality of service (QoS) for video applications requires the network to select optimum path among multiple paths to improve application performance. Multiple network paths from source to destination may be available but due to the current network high coupling design identifying alternate paths is difficult. The path selection process should be adaptive to changing network conditions (e.g., link and node failures) and should be context aware about the state of path (i.e., bandwidth, jitter and delay).

CHAPTER 2: BACKGROUND STUDY

Paper: SURVEY ON SOFTWARE DEFINED NETWORKING

Year: 2015

Publisher: IEEE

Summary: Recent developments in ICT domain, for example, mobile, multimedia, cloud, and big data, are demanding for more convenient Internet access, more bandwidth from users, as well as more dynamic management from service providers. SDN is considered as a promising solution to meet these demands. In this paper, we have presented the concept of SDN and highlighted benefits of SDN in offering enhanced configuration, improved performance, and encouraged innovation. Moreover, we have provided a literature survey of recent SDN researches in the infrastructure layer, the control layer, and the application layer

[2.2]

Paper: SURVEY ON CUSTOM TOPOLOGY FRAMEWORK USING MININET

Year: 2014

Publisher: RESEARCH GATE

Summary: In any organization, actual network is not confined to simple topologies like linear or tree. The real network topologies in these organizations are complex and represent more like hierarchical/ graph connectivity. The switches and nodes are at different depth and even the fan out isdifferent.

Thus, for Mininet to be as close to real network as possible, some enhancements are required. In the proposed framework, any topology that is of interest to the user can be created resembling the real network. Care has been taken not to affect the performance of Mininet by doing thisenhancement.

[2.3]

Paper: VIDEO OVER SOFTWARE DEFINED NETWORKING (VSDN)

Year: 2013

Publisher: RESEARCH GATE

Summary: Software-defined Networking (SDN) is a promising network architecture for future internet applications by seperating the control and data layer of computer networks. On the other hand, Application Layer Traffic Optimization (ALTO) protocol provides ISP-friendly communication by provisioning network related information to the applications. In this paper, we propose a method for selecting appropriate video server using SDN and ALTO in content distribution network (CDN) based video streaming systems. Simulation results show that with the proposed method, the quality of experience received by the clients in video streaming applications is increased and the communication cost between internet service providers is reduc

CHAPTER 3: REQUIREMENT ANALYSIS

3.1 Software Requirements

3.1.1 Environment used:

- OpenFlow
- Python
- Mininet
- FloodLight

3.1.2 Other Requirements:

- Python 3 or higher
- POX Controller
- Iperf tool
- Wireshark

3.2 Hardware Requirements

- Linux Operating System
- Processor: Intel ® Core (TM) i5 -6200U CPU @2.30GHz 2.40GHz
- Ram : 4 GB and above
- Disk Space : 5 GB

3.3 Functional Requirements

- Hosts
- Eligible software to implement our ideas.
- Suitable libraries for using algorithm in the source code.

3.4 Non-functional Requirements

- Network Stimulator

CHAPTER 4: DETAILED DESIGN

4.1.1 Architecture

SDN provides separation between the control plane (controller) and data plane (switch) functions of networks using a protocol that modifies forwarding tables in network switches. This makes it possible to optimize networks on the fly and quickly respond to changes in network usage without the need for manually reconfiguring existing infrastructure or purchasing new hardware. SDN separates the control of network devices from the data they transport, and the switching software from the actual network hardware.

It also provides an entity, the controller, that has a comprehensive view of the entire network and its status, and with which switches (network resources) and applications (network consumers) can communicate in real-time. The controller makes it possible for networks to interact with applications and efficiently reconfigure themselves at need, allowing them to implement multiple logical network topologies on a single common network fabric.

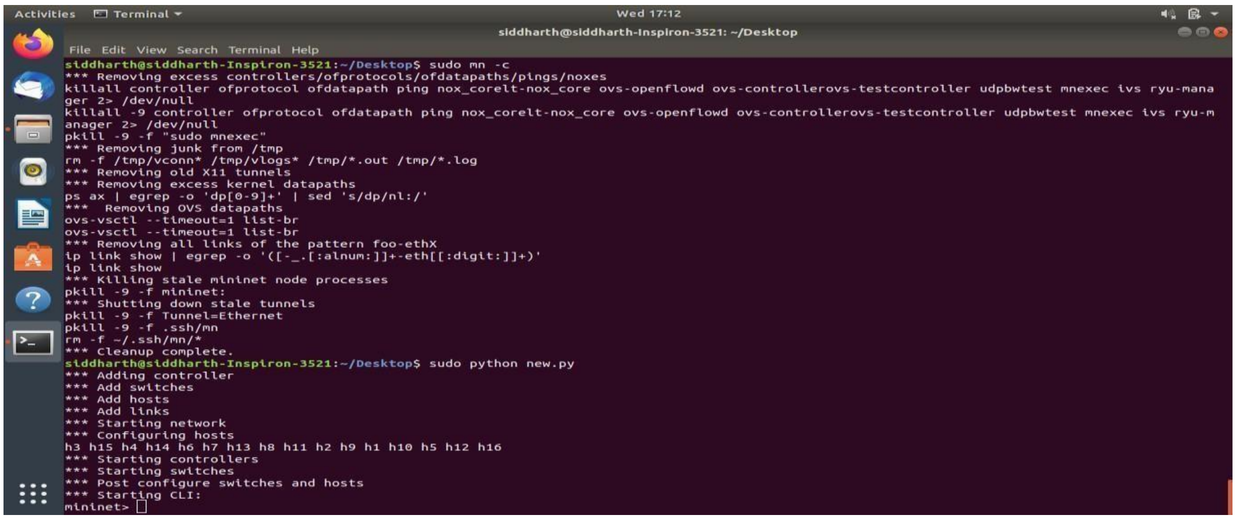
4.1.2 Custom Topology in mininet

Custom topologies can be easily defined as well, using a simple Python API, and an example is provided in custom/topo-2sw-2host.py. This example connects two switches directly, with a single host off each switch

```
from mininet.topo import Topo class
MyTopo( Topo )
def init ( self ):

"Create custom topo." Topo.
init ( self )
leftHost = self.addHost( 'h1' ) #ADD HOST AND SWITCH
rightHost = self.addHost( 'h2' )
leftSwitch = self.addSwitch( 's3' )
rightSwitch = self.addSwitch( 's4' )

self.addLink( leftHost, leftSwitch )#ADD LINKS
self.addLink( leftSwitch, rightSwitch ) self.addLink(
rightSwitch, rightHost )


topos = { 'mytopo': ( lambda: MyTopo() )
```

CHAPTER 5: IMPLEMENTATION

We started with the implementation of a basic topology using mininet .Our main idea is to make custom topology in python which mimic ERNET run with POX controller.For this we made different basic topology to understand the basics of mininet custom topology

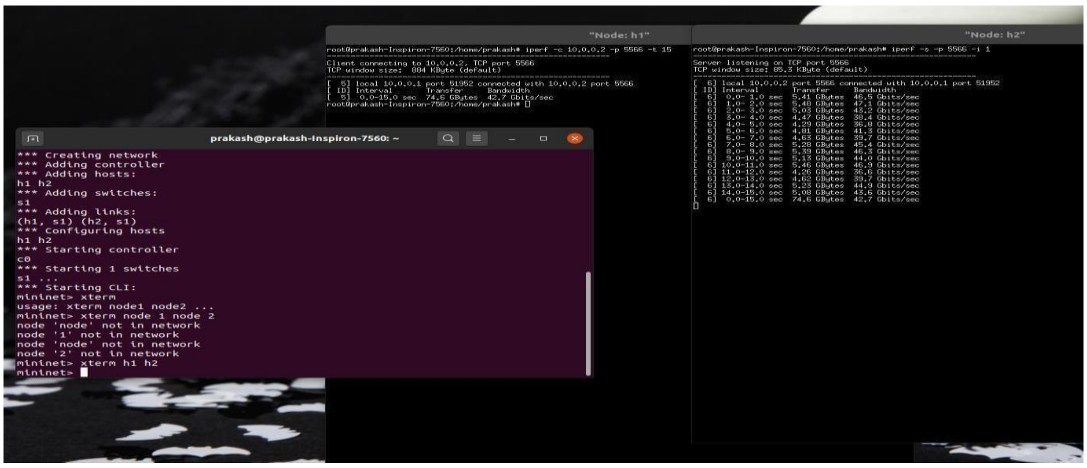

Activities
Terminal
Wed 17:12
siddharth@siddharth-Inspiron-3521: ~/Desktop
File Edit View Search Terminal Help

```
siddharth@siddharth-Inspiron-3521:~/Desktop$ sudo mn -c
*** Removing excess controllers/ofprotocols/ofdatapaths/pings/noxes
killall controller ofprotocol ofdatapath ping nox_corelt-nox_core ovs-openflowd ovs-controllerovs-testcontroller udpbwtest mnexec ivs ryu-mana
ger 2> /dev/null
killall -9 controller ofprotocol ofdatapath ping nox_corelt-nox_core ovs-openflowd ovs-controllerovs-testcontroller udpbwtest mnexec ivs ryu-m
anager 2> /dev/null
pkill -9 -f "sudo mnexec"
*** Removing junk from /tmp
rm -f /tmp/vconn* /tmp/vlogs* /tmp/*.out /tmp/*.log
*** Removing old X11 tunnels
*** Removing excess kernel datapaths
ps ax | egrep -o 'dp[0-9]+' | sed 's/dp/nl:/'
***  Removing OVS datapaths
ovs-vsctl --timeout=1 list-br
ovs-vsctl --timeout=1 list-br
*** Removing all links of the pattern foo-ethX
ip link show | egrep -o '([-_.[:alnum:]]+-eth[[:digit:]]+)'
ip link show
*** Killing stale mininet node processes
pkill -9 -f mininet:
*** Shutting down stale tunnels
pkill -9 -f Tunnel=Ethernet
pkill -9 -f .ssh/mn
rm -f ~/.ssh/mn/*
*** Cleanup complete.
siddharth@siddharth-Inspiron-3521:~/Desktop$ sudo python new.py
*** Adding controller
*** Add switches
*** Add hosts
*** Add links
*** Starting network
*** Configuring hosts
h3 h15 h4 h14 h6 h7 h13 h8 h11 h2 h9 h1 h10 h5 h12 h16
*** Starting controllers
*** Starting switches
*** Post configure switches and hosts
*** Starting CLI:
mininet> 
```

Figure-5.1 Simple HTTP Server connection

Then we moved further to use iperf to do basic performance evaluation over mini net. Also, we used simple shell script to get the evaluation results and then use gnu-plot to draw the graph.

We created one switch and two hosts environment,then used xterm to open windows for h1 and h2.For the basic TCP transmission evaluation we started TCP server (-s) at h2 with port 5566 (-
p) and monitoring the results every second (-i). Then started TCP client (-c) at h1,and also set the transmission duration (-t) to 15 sec.



```
root@prakash-Inspiron-7560:/home/prakash# iperf -c 10.0.0.2 -p 5566 -t 15
------------------------------------------------------------
Client connecting to 10.0.0.2, TCP port 5566
TCP window size:  884 KByte (default)
------------------------------------------------------------
[  5] local 10.0.0.1 port 51952 connected with 10.0.0.2 port 5566
[ ID] Interval       Transfer     Bandwidth
[  5]  0.0-15.0 sec  74.6 GBytes  42.7 Gbits/sec
root@prakash-Inspiron-7560:/home/prakash# 
```

```
root@prakash-Inspiron-7560:/home/prakash# iperf -s -p 5566 -i 1
------------------------------------------------------------
Server listening on TCP port 5566
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  6] local 10.0.0.2 port 5566 connected with 10.0.0.1 port 51952
[ ID] Interval       Transfer     Bandwidth
[  6]  0.0- 1.0 sec  5.41 GBytes  46.5 Gbits/sec
[  6]  1.0- 2.0 sec  5.48 GBytes  47.1 Gbits/sec
[  6]  2.0- 3.0 sec  5.03 GBytes  43.2 Gbits/sec
[  6]  3.0- 4.0 sec  4.47 GBytes  38.4 Gbits/sec
[  6]  4.0- 5.0 sec  4.29 GBytes  36.8 Gbits/sec
[  6]  5.0- 6.0 sec  4.81 GBytes  41.3 Gbits/sec
[  6]  6.0- 7.0 sec  4.63 GBytes  39.7 Gbits/sec
[  6]  7.0- 8.0 sec  5.28 GBytes  45.4 Gbits/sec
[  6]  8.0- 9.0 sec  5.39 GBytes  46.3 Gbits/sec
[  6]  9.0-10.0 sec  5.13 GBytes  44.0 Gbits/sec
[  6] 10.0-11.0 sec  5.46 GBytes  46.9 Gbits/sec
[  6] 11.0-12.0 sec  4.26 GBytes  36.6 Gbits/sec
[  6] 12.0-13.0 sec  4.62 GBytes  39.7 Gbits/sec
[  6] 13.0-14.0 sec  5.23 GBytes  44.9 Gbits/sec
[  6] 14.0-15.0 sec  5.08 GBytes  43.6 Gbits/sec
[  6]  0.0-15.0 sec  74.6 GBytes  42.7 Gbits/sec
```

```
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet> xterm
usage: xterm node1 node2 ...
mininet> xterm node 1 node 2
node 'node' not in network
node '1' not in network
node 'node' not in network
node '2' not in network
mininet> xterm h1 h2
mininet> 
```

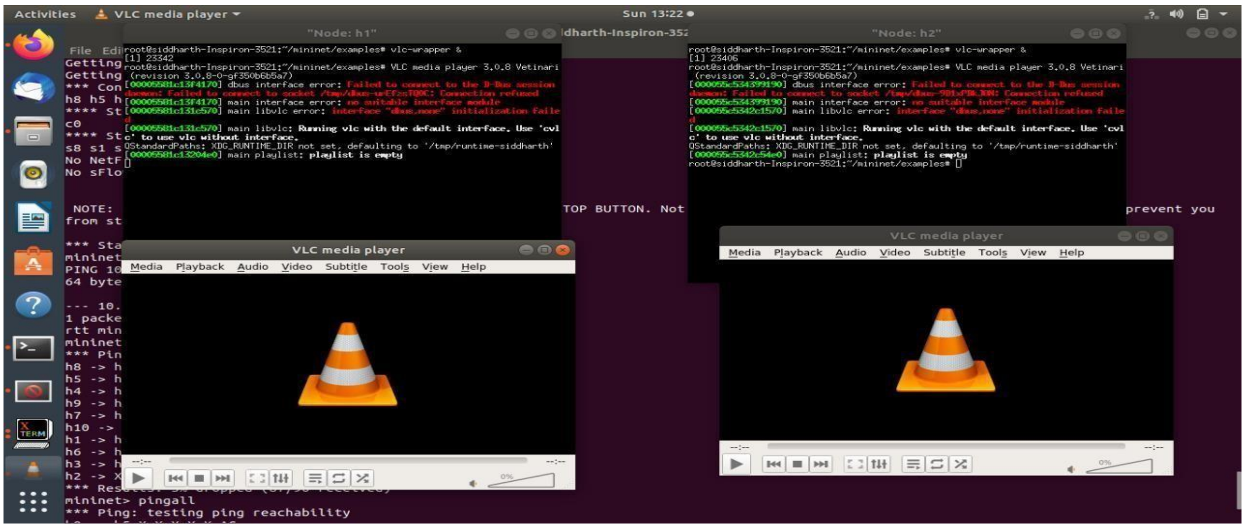
Figure 5.2- Basic TCP transmission evaluation

After this we tried to stream vlc using mininet in the topology created.

Opening mininet topology we created and hit-- xterm

h1 h2

this creates two xterm windows and open vlc on both using vlc-wrapper &.



```
root@siddharth-Inspiron-3521:~/mininet/examples# vlc-wrapper &
[1] 23342
root@siddharth-Inspiron-3521:~/mininet/examples# VLC media player 3.0.8 Vetinari
 (revision 3.0.8-0-gf350b6b5a7)
[00005581c13f4170] dbus interface error: Failed to connect to the D-Bus session
daemon: Failed to connect to socket /tmp/dbus-urEfzsTQ0C: Connection refused
[00005581c13f4170] main interface error: no suitable interface module
[00005581c131c570] main libvlc error: interface "dbus,none" initialization faile
d
[00005581c131c570] main libvlc: Running vlc with the default interface. Use 'cvl
c' to use vlc without interface.
QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-siddharth'
[00005581c13204e0] main playlist: playlist is empty
```

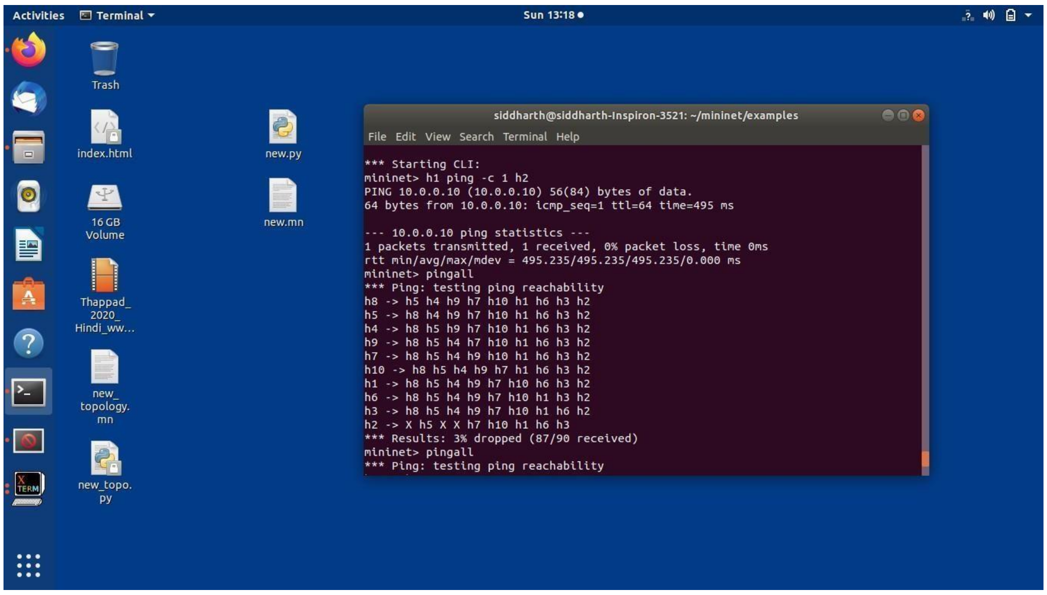
```
root@siddharth-Inspiron-3521:~/mininet/examples# vlc-wrapper &
[1] 23406
root@siddharth-Inspiron-3521:~/mininet/examples# VLC media player 3.0.8 Vetinari
 (revision 3.0.8-0-gf350b6b5a7)
[000055c534399190] dbus interface error: Failed to connect to the D-Bus session
daemon: Failed to connect to socket /tmp/dbus-901xPIkJNN: Connection refused
[000055c534399190] main interface error: no suitable interface module
[000055c5342c1570] main libvlc error: interface "dbus,none" initialization faile
d
[000055c5342c1570] main libvlc: Running vlc with the default interface. Use 'cvl
c' to use vlc without interface.
QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-siddharth'
[000055c5342c54e0] main playlist: playlist is empty
root@siddharth-Inspiron-3521:~/mininet/examples# 
```

```
mininet> pingall
*** Ping: testing ping reachability
```

Figure 5.3: Configuring VLC on h1 and h2

Now we go to Stream option on VLC and add video files which needs to be streamed and change destination to RTP/MPEG Transport system. Then,put the destination address and configure other details and finally get the video streamed .

CHAPTER 6: TESTING REPORTS AND RESULTS



```
*** Starting CLI:
mininet> h1 ping -c 1 h2
PING 10.0.0.10 (10.0.0.10) 56(84) bytes of data.
64 bytes from 10.0.0.10: icmp_seq=1 ttl=64 time=495 ms

--- 10.0.0.10 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 495.235/495.235/495.235/0.000 ms
mininet> pingall
*** Ping: testing ping reachability
h8 -> h5 h4 h9 h7 h10 h1 h6 h3 h2
h5 -> h8 h4 h9 h7 h10 h1 h6 h3 h2
h4 -> h8 h5 h9 h7 h10 h1 h6 h3 h2
h9 -> h8 h5 h4 h7 h10 h1 h6 h3 h2
h7 -> h8 h5 h4 h9 h10 h1 h6 h3 h2
h10 -> h8 h5 h4 h9 h7 h1 h6 h3 h2
h1 -> h8 h5 h4 h9 h7 h10 h6 h3 h2
h6 -> h8 h5 h4 h9 h7 h10 h1 h3 h2
h3 -> h8 h5 h4 h9 h7 h10 h1 h6 h2
h2 -> X h5 X X h7 h10 h1 h6 h3
*** Results: 3% dropped (87/90 received)
mininet> pingall
*** Ping: testing ping reachability
```

Figure-6.1 Testing network reachability

For the TCP transmission obtained using iperf we use gnuplot to plot the graph.

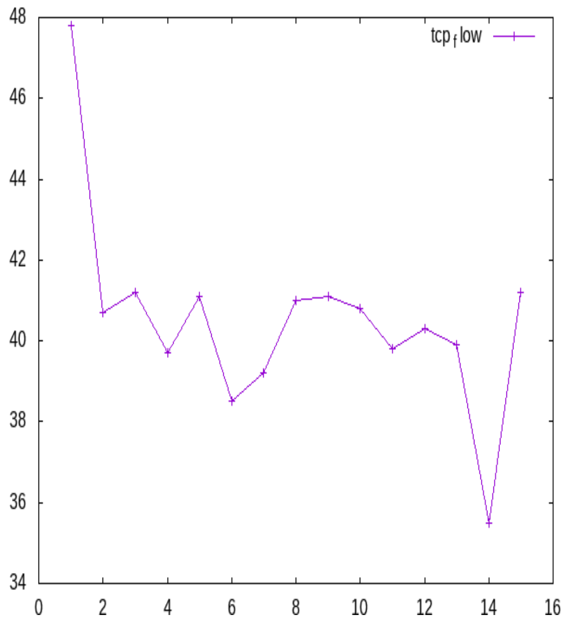
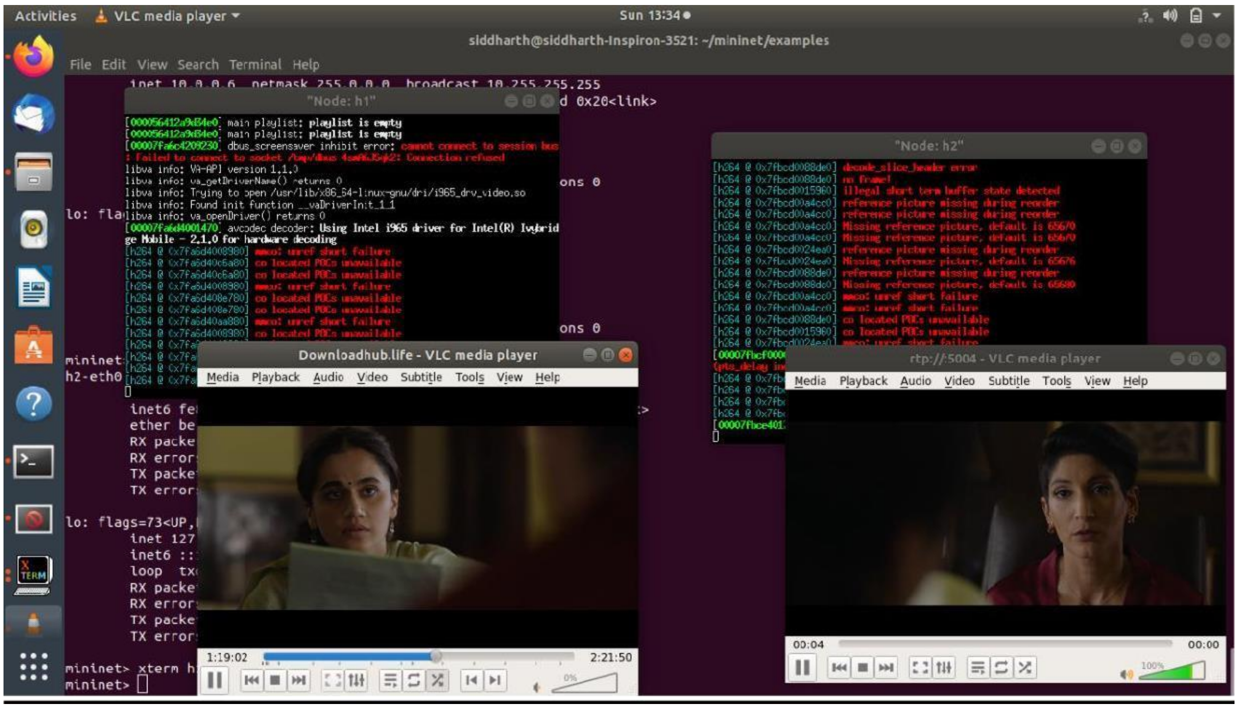


Figure 6.2: TCP transmission graph obtained using gnuplot


Activities
VLC media player
Sun 13:34
siddharth@siddharth-Inspiron-3521: ~/mininet/examples
File Edit View Search Terminal Help
"Node: h1"
Downloadhub.life - VLC media player
Media Playback Audio Video Subtitle Tools View Help
1:19:02
2:21:50
"Node: h2"
rtp://:5004 - VLC media player
Media Playback Audio Video Subtitle Tools View Help
00:04
00:00

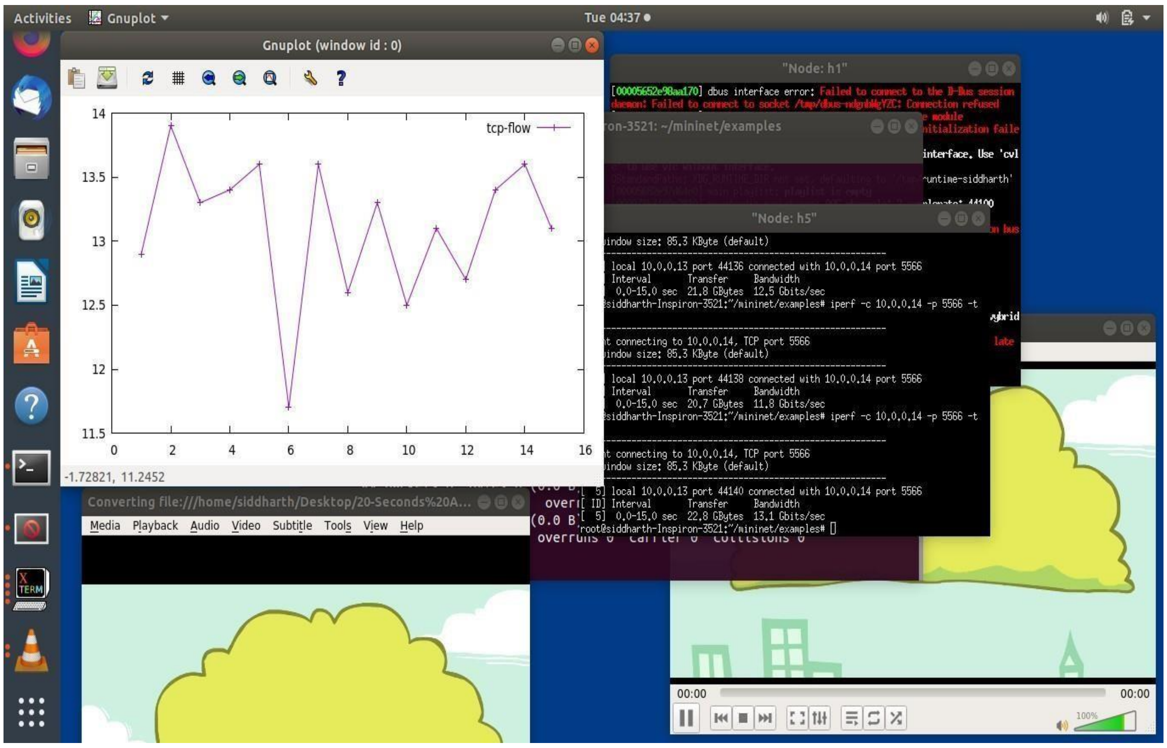
```
inet 10.0.0.6  netmask 255.0.0.0  broadcast 10.255.255.255
```

```
[000056412a9d84e0] main playlist: playlist is empty
[000056412a9d84e0] main playlist: playlist is empty
[00007fa6c4209230] dbus_screensaver inhibit error: cannot connect to session bus
: Failed to connect to socket /tmp/dbus 4saR6J5q#2: Connection refused
libva info: VA-API version 1.1.0
libva info: va_getDriverName() returns 0
libva info: Trying to open /usr/lib/x86_64-linux-gnu/dri/i965_drv_video.so
libva info: Found init function __vaDriverInit_1_1
libva info: va_openDriver() returns 0
[00007fa6d4001470] avcodec decoder: Using Intel i965 driver for Intel(R) Ivybrid
ge Mobile - 2.1.0 for hardware decoding
[h264 @ 0x7fa6d4008980] mmco: unref short failure
[h264 @ 0x7fa6d40c6a80] co located POCs unavailable
[h264 @ 0x7fa6d40c6a80] co located POCs unavailable
[h264 @ 0x7fa6d4008980] mmco: unref short failure
[h264 @ 0x7fa6d408e780] co located POCs unavailable
[h264 @ 0x7fa6d408e780] co located POCs unavailable
[h264 @ 0x7fa6d40aa880] mmco: unref short failure
[h264 @ 0x7fa6d4008980] co located POCs unavailable
```

```
[h264 @ 0x7fbcd0088de0] decode_slice_header error
[h264 @ 0x7fbcd0088de0] no frame!
[h264 @ 0x7fbcd0015960] illegal short term buffer state detected
[h264 @ 0x7fbcd00a4cc0] reference picture missing during reorder
[h264 @ 0x7fbcd00a4cc0] reference picture missing during reorder
[h264 @ 0x7fbcd00a4cc0] Missing reference picture, default is 65670
[h264 @ 0x7fbcd00a4cc0] Missing reference picture, default is 65670
[h264 @ 0x7fbcd0024ea0] reference picture missing during reorder
[h264 @ 0x7fbcd0024ea0] Missing reference picture, default is 65676
[h264 @ 0x7fbcd0088de0] reference picture missing during reorder
[h264 @ 0x7fbcd0088de0] Missing reference picture, default is 65680
[h264 @ 0x7fbcd00a4cc0] mmco: unref short failure
[h264 @ 0x7fbcd00a4cc0] mmco: unref short failure
[h264 @ 0x7fbcd0088de0] co located POCs unavailable
[h264 @ 0x7fbcd0015960] co located POCs unavailable
[h264 @ 0x7fbcd0024ea0] mmco: unref short failure
```

```
mininet> xterm h
mininet>
```

Figure 6.3: Video streaming in VLC



```
[00005652e98aa170] dbus interface error: Failed to connect to the D-Bus session
daemon: Failed to connect to socket /tmp/dbus-ndgnbWgYZC: Connection refused
```

```
window size: 85.3 KByte (default)
------------------------------------------------------------
 local 10.0.0.13 port 44136 connected with 10.0.0.14 port 5566
 Interval       Transfer     Bandwidth
  0.0-15.0 sec  21.8 GBytes  12.5 Gbits/sec
@siddharth-Inspiron-3521:~/mininet/examples# iperf -c 10.0.0.14 -p 5566 -t

------------------------------------------------------------
nt connecting to 10.0.0.14, TCP port 5566
window size: 85.3 KByte (default)
------------------------------------------------------------
 local 10.0.0.13 port 44138 connected with 10.0.0.14 port 5566
 Interval       Transfer     Bandwidth
  0.0-15.0 sec  20.7 GBytes  11.8 Gbits/sec
@siddharth-Inspiron-3521:~/mininet/examples# iperf -c 10.0.0.14 -p 5566 -t

------------------------------------------------------------
nt connecting to 10.0.0.14, TCP port 5566
window size: 85.3 KByte (default)
------------------------------------------------------------
[  5] local 10.0.0.13 port 44140 connected with 10.0.0.14 port 5566
[ ID] Interval       Transfer     Bandwidth
[  5]  0.0-15.0 sec  22.8 GBytes  13.1 Gbits/sec
root@siddharth-Inspiron-3521:~/mininet/examples# 
```

Fig 6.4 Performance analysis using openflow controller

CHAPTER 7: CONCLUSION AND FUTURE SCOPE

SDN provides a platform to implement various SDN applications. SDN applications can access a global network view and cross-layer information to make better network operation decisions. Mininet provides programming support for the same. To create custom topologies, one has to write programs by modifying the existing Mininet code which may be a tedious job for a general user. In the proposed work, efforts are made towards creating a user friendly framework in Mininet which supports the creation of user defined topology as ERNET (Education and Research Network). SDN has a problematic future as it has issues to overcome. The first issue is the console/remote capability with today’s security issues many will not want to expose their network to a potential hacker takeover. It is an Open Source Technology! Another issue is the current state of Network Management policies and practices with single device or single path focus. When a Network Manager looks at SDN he only sees how it can help or hurt his network but SDN is much bigger and a lot of education still remains to be done to make SDN or similar technologies palatable.SDN is a Human Centric Technology where today’s technology is Device Centric which is and always will be a challenge to get managers to adopt especially when one person can completely change your network, storage, WAN..etc fabric. SDN opens lots of questions for the future of advance networking and computing technologies. We need more responsive technology but not at the cost of security and control. In the long run SDN may be deployed in provider networks but individual corporations may find it just too much to deploy. SDN is in need of a lot more development and proof of being a secure and deployable technology. SDN seek to drive a future software-based 5G networking solution that offers a flexible and automated feature selection for network connectivity and QoE provisioning to the end-users.

REFERENCES

[1] O.N. F. (ONF), “SOFTWARE DEFINE NETWORKING: The new norm for networks,” https://www.opennetworking.org/images/stories/downloads/white- papers/wp-sdnnewnorm.pdf, 2012.

[2] P. Fonseca, R. Bennesby, E. Mota and A, Passito, “A replication component for resilient openflow based networking”, NOMS, 2012.

[3] S. Shenker and C. Partridge, “Specification of guaranteed quality of service,” http://www.ietf.org/rfc/rfc2212.txt, 1997, RFC 2212.