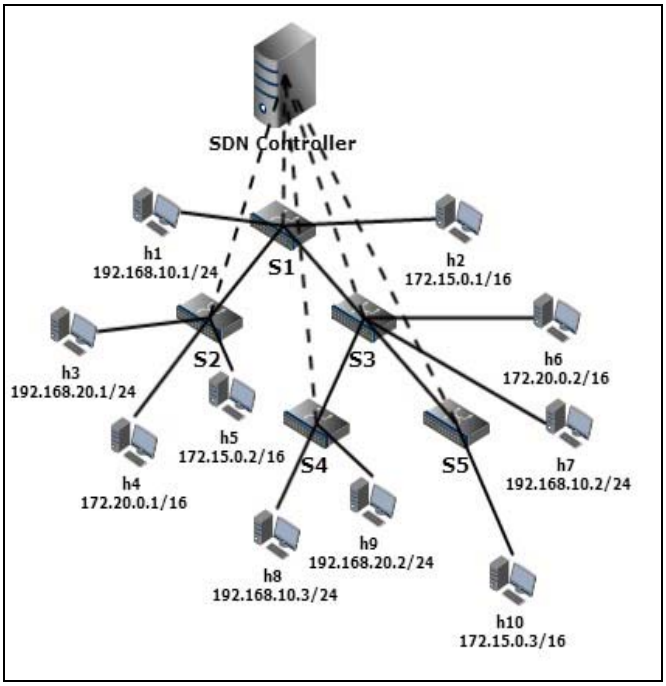

Figure 9: Custom Topology with Multiple IP Network Addresses

Normally in real networks different links can have different parameters. An example of such a configuration file for the topology diagram in Figure 11 is as shown in Figure 10. Thus user can create the topology of his/her choice easily by specifying one configuration file. If the link parameters are not specified in the configuration file then the default values will be taken.

```
#Network Numbers
192.168.20.0/8
172.15.0.0/16;
#Switch, host Connectivity with link parameters
s1-h1(BW=20)-s2(BW=10, Delay='10ms')-s3(BW=20, Delay = '5ms'-h2(BW=10)
s2-h3(BW=10)-s4(BW=20, Delay='5ms', Loss=10)
s3-h4(BW=10)-h5(BW=5, Delay = '5ms')-h6(BW = 5, Delay= '10ms')
s4-h7(BW = 10, Delay = '10ms') -h8(BW = 10, Delay = '10ms');;
#IP to host Details
h1-2
h2-1
h3-2
h4-2
h5-1
h6-2
h7-1
```

Figure 10: Configuration for Custom Topology with Different Link Parameters

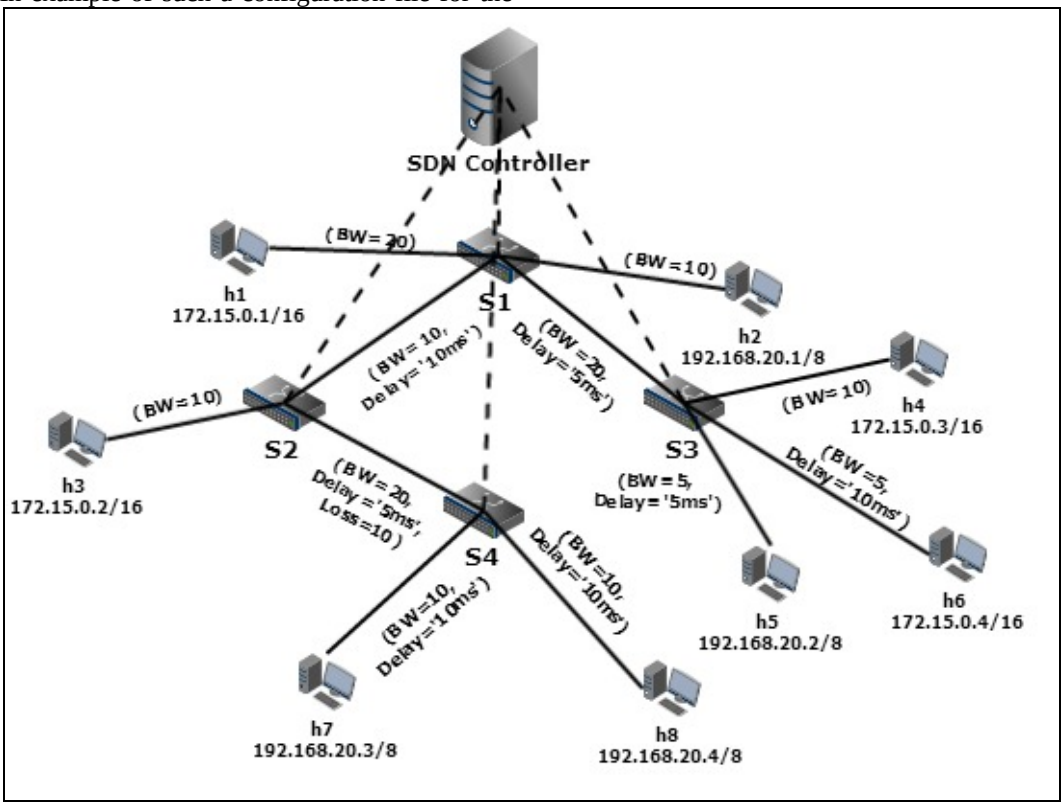

Figure 11: Custom Topology with Different Link Parameters

The host belonging to one network is reachable from any other host within the same group. This can be verified using the '*ping*' command. If the host belongs to different group then the packet need to be forwarded through the network element working as L3 switch designated by controller. In future, this is planned to be handled by enhancing the controller functionality.

In the current framework, care should be taken not to create loops in the network while creating the configuration file. The framework allows for creation of loops and does not make a check. If topology contains the loops, then unless the controller implements spanning tree algorithm, any packet sent in the network may cause network flooding and broadcast storm and thus prevent one host from communicating with the other hosts.

4. Performance Study

After adding the proposed framework into the original Mininet the time taken for the creation of topology in original Mininet as well as in the enhanced Mininet was compared. The experiments were repeated on two different test setups; a) running the Mininet installed on the native machine, and b) running Mininet under VirtualBox. Studies were conducted by varying the number of switches created and the number of hosts created in the topology. The results obtained are given in the Table I.

Table I: Creation Time for Custom Topologies

Sl. No	*No. of Switches (No. of Hosts)*	*Avg Time taken in seconds*	
		Existing Mininet	*Enhanced Mininet*
1	Sl(5)	0.45	0.41
2	Sl(5)S2(10)	1.09	1.19
3	Sl(5)S2(10)S3(15)	2.39	2.53
4	Sl(5)S2(10)S3(15) S4(20)	3.9	4.18
5	Sl(5)S2(10)S3(15)S4(20) S5(25)	6.11	6.72

The graphical depictions for the results of Table I is shown in Figure.12.

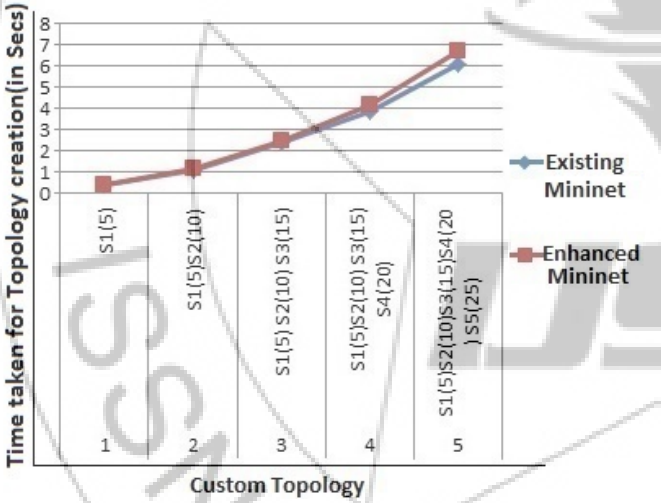

Figure 12: Creation of Custom Topology

The experiments were repeated by creating different network domains in the same topology. Again the number of switches created and the number of hosts created is varied and time taken to create the topology is analyzed. The results obtained are given in Table II

Table 2: Creation Time for Multiple Broadcast Domains

Sl. No	*No. of Switches (No. of Hosts)*	*Avg Time taken in seconds*	
		Existing Mininet	*Enhanced Mininet*
1	Sl(5)	0.48	0.338
2	Sl(5)S2(10)	1.1	1.19
3	Sl(5)S2(10)S3(15)	2.43	2.55
4	Sl(5)S2(10)S3(15)S4(20)	3.9	4.19
5	Sl(5)S2(10)S3(15)S4(20)S5(25)	6.14	6.7

The graphical depiction for the results of Table II is shown in Figure 13.

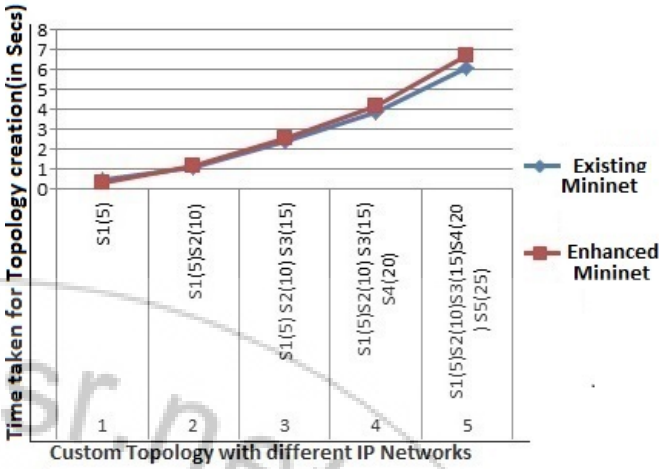

Figure 13: Creation of Different Broadcast Domains

The results show that the performance (time taken) by the original Mininet and the Enhanced Mininet supporting creation of different topologies is comparable. As the number of switches and the number of hosts increase there is a slight increase (less than 10%) in the time taken by the Enhanced Mininet, but still this increase is negligible when compared to the ease at which the custom topology can be created. This framework is very much useful for the researchers to create the topologies of their interest to test their ideas and protocols.

5. Conclusion and Future Work

Mininet emulator is a handy tool for networking researchers to emulate real operational network and to test their innovative ideas and new protocols. As it is openflow enabled, it is very much suitable for SDN research. Existing Mininet is enhanced to create topologies which model the real time network topologies by specifying different depth and fan-out, creating different broadcast domains, specifying different link parameters etc. in a user friendly manner. The topology can be specified either through the command line or through the configuration file. The experimental results show that the time taken for the creation of topology of user's choice practically remains unaffected by this additional feature. Users working on data center research can also create different topologies like fat-trees for their experiments.

In future, one can work on implementing spanning tree algorithm in SDN controller to handle loops in the custom topology and to forward the packets between different networks. Similarly, other data center technologies such as TRILL can be implemented in controller and Mininet can be upgraded accordingly.

References

[1] Roberto Bifulco, Roberto Canonico, Marcus Brunner, Peer Hasselmeyer, Faisal Mir, " A Practical Experience in Designing an Openflow Controller", European Workshop on Software Defined Networking, 2012.

[2] Kostas Choumas, Nikos Makris, Max Ott, "Exploiting Openflow Resources towards a Content-Centric LAN", Second European Workshop on Software Defined Networks, 2013.
[3] P.Fonseca, R. Bennesby, E. Mota and A, Passito, "A replication component for resilient openflow-based networking", NOMS, 2012.
[4] GENI – Global Environment for Network Innovation Available: http://www.geni.net.
[5] Nikhil Handigol, Brandon Heller, Vimalkumar Jeyakumar, Bob Lantz and Nick McKeown, " Reproducible Network Experiments Using Container-Based emulation", CoNEXT, December, 2012.
[6] Bob Lantz, Brandon Heller and Nick McKeown "A Network in a Laptop: Rapid Prototyping for Software-Defined Networks", Hotnets, October 2010.
[7] Nick Mckeown, Tom Anderson, Hari Balakrishnan, Guru Parulkar, Larry Peterson, Jennifer Peterson, Scott Shenker, Jonathan Turner, 'OpenFlow: Enabling Innovation in Campus Networks', *ACM SIGCOMM Computer Communication Review, Volume 38, Number 2, April 2008*.
[8] Mininet Available: http://www.openflow.org/wk/index.php/OpenFlow_Tutorial http://mininet.org/overview/
[9] Msahil M, Pujolle G, Serhrenchni A, Fadlallah A, Guenane F, "Openflow and on demand Networks", Third international conference on "Network of the Future" Nov, 2012.
[10] Netem – Network Emulator Available: http://www.linuxfoundation.org/collaborate/workgroups/networking/netem
[11] NS2 Available : http://www.isi.edu/nsnam/ns/ NS3 Available : http://www.nsnam.org/
[12] OMNeT++ Available:http://www.omnetpp.org/ Openflow Protocol http://www.openflow.org/wp/learnmore/
[13] OPNET Modeller http://www.opnet.com/
[14] Jilani Pan, Raj Jain, "A survey of Network Simulation tools – Current status and Future Development", project report, Nov, 2008.
[15] Peter Peresini, Maciej Kuzniar and Dejan Kostic, "Openflow needs you! A call for a Discussion about a Cleaner Openflow API", Second European Workshop on Software Defined Networks, 2013.
[16] Planet Lab Available: https://www.planet-lab.org/node/263
[17] Software Defined Networks https://www.opennetworking.org/sdn-resources/sdn-definition

Author Profile

Mrs. Veena S. holds M.C.A. degree from MCE, Hassan, University of Mysore and M. Tech. Degree from AAIDU Allahabad. She is currently pursuing her Ph.D. under VTU in the area of Software Defined Networks. Mrs. Veena has 18 years of teaching experience in various institutions and taught post-graduate, under-graduate and Diploma students in different areas. She has completed her Instructor Training for CCNA Exploration (now Routing and Switching) Modules 1 through 4 from Cisco Networking Academy and training students for the CCNA Routing and Switching course. She has also been an invited speaker in Network Hands-On workshops as well as imparting hands-on training on IPv6 networking. Currently she is working as Associate Professor at PESIT, Bangalore, India.

Dr. Ram P Rustagi, a senior IEEE member, is working as Professor, Info Sc & Engg Dept, PESIT and teaching Undergraduates, Post Graduates as well as guiding few Research scholars. Prior to joining PESIT, he was Vice President at Kirusa Software Pvt Ltd, India/USA. As VP, he developed applications in Cellular VAS areas, He also managed Deployment and Operations Support for Kirusa's customers in India and APAC region. Besides academic activity, he is working on few research projects as per grants received from Pluribus Networks, USA, Kirusa Software, Bangalore, India. . He is also serving as a member of board of directors with M/s Altima Technologies Inc, USA. *Academic background*: Ph.D from IIT Delhi, India, 1998 and M.Tech from Indian Institute of Science, Bangalore, India, 1981.

Dr. K. N. Balasubramanya Murthy is currently the Vice-Chancellor of PES University, Bangalore. Dr. Murthy has served PES Institute of Technology (PESIT), Bangalore as the Principal & Director from 2005 to 2014 and has over 30 years of experience in Teaching, Training, research, industry and Administration. He holds a Bachelors in Electrical power Engineering from University of Mysore (1980), Masters in Electrical Engineering from Indian Institute of Science, Bangalore (1986) and Ph.D. in Computer Science and Engineering from Indian Institute of Technology - Madras, Chennai (1996). He was invited to New Mexico State University as a research specialist in Parallel Computing during the year 1998-99. He served Malnad College of Engineering, Hassan as a faculty in Electrical Engineering and East West Institute of Technology, Bangalore as its Founder Principal. Dr. Murthy has supervised 4 research scholars for Ph.D. degree and authored over 90 research papers in reputed journals and conferences. He served as a member of the Academic Senate and Executive Council as well as several academic committees of Visvesvaraya Technological University (VTU) - Belgaum of Karnataka. He was a Board member of BITES under the chairmanship of Prof.R.Natarajan for a period of three years during 2008-11. He is currently serving as a member of a committee constituted by Karnataka Knowledge Council (KKC) for recommending mechanisms to enhance employability of Engineering graduates in the state of Karnataka under chairmanship of Prof.G.Padmanabhan of IISc.