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Performance Analysis of Traditional Networks with Software Defined Networks (SDN) over Various Topologies Using Mininet

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Abstract: Software defined networking (SDN) is rising and upcoming field of networking. The primary concept of SDN is that the control plane is decoupled from data plane, so it will manage the data traffic smoothly over the entire network. Many problems in traditional networks are arrived day by day such as increasing scalability, security, reliability and speed of the network. These problems can be overcome by applying the concept of SDN. The current network infrastructure of Mehran University of Engineering & Technology (MUET), Jamshoro, Pakistan is based on traditional network that has several problems including limited bandwidth, vendor specific devices and no virtualization. The idea is to analyze the performance of traditional and SDN networks over different topologies and integrate the SDN network in faculty of Electronics, Electrical & Computer Engineering (FEECE) of Mehran University of Engineering & Technology (MUET), Jamshoro, Pakistan. Traditional networks are evaluated on GNS-3 and SDN networks are evaluated on Mininet. Round-Trip-Time, throughput, initial packet time and bandwidth for both networks were analyzed in this paper.

Keywords: Software Defined Network (SDN), Traditional Network, MUET Jamshoro, Pakistan, Bandwidth, Round-Trip-Time, Network Design.

I. Introduction

Traditional networks are hardware-based networks. They were stable and reliable in older days. They work using protocols. They are static and inflexible and possess little agility. In traditional networking switches and routers controls the flow of data with following three elements Control Plane, Data Plane and Management Plane (APP) as shown in Fig.1. Normally in traditional networks, switches perform network routing that has built-in routing mechanism [1]. Traditional networks may take years to upgrade features, introduce new devices and adjust architectures, to support new service requirements. In traditional networks Security and traffic flow are also major issues.

Figure 1: Traditional Network Architecture

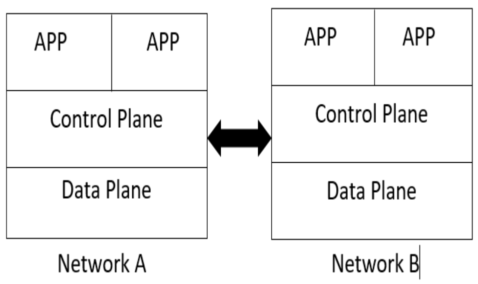
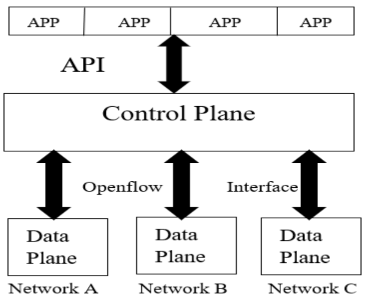


Figure 2: SDN Network Architecture



SDN is technique of networking that gives permission to network managers to manage network services by the conception of lower level functions. SDNaimstoaddressthefact that the stationary design of traditional or conventional networks does not provide the scalable, robust computing and storage demands of modern computing environments such as data centers [2]. This can be approved by separating or dividing the system that decides about where traffic is circulated (control plane) from the rudimentary systems that send traffic to the chosen destination (data plane). In the SDN control plane is decoupled from data plane as shown in Fig.2, so it can manage the data traffic smoothly over the entire network. The central SDN controller will manage, handle and control the packets where they will be forwarded.

The work in this paper is divided into following sections. Section II elaborates the literature review, whereas problem statement is explained in section III. Section IV describes the aims and objectives of the paper while section V explains the experimental method. Section VI is related to performance results and finally conclusion is given in section VIII.

II. Literature Review

In this paper [3], researchers have examined different SDN controllers and tree topology was considered in the experiment. Parameters that were used in that research were ping and initial packet latency. It was observed that when using floodlight controller in tree topology, greater performance can be achieved. Similarly, in another study [4], performance of open daylight SDN controller was examined. Researchers have proposed a new architecture for stable performance, and it was observed that open daylight controller have several problems such as memory leakages and low bandwidth. The work in [5], comes with an examination as the performance of floodlight controller was analyzed using linear topology. Analysis was done using Mininet software and total time when creating topology and system memory were examined and it was observed that floodlight controller takes more memory as number of users increases. In this research [6], bandwidth Management of Software Defined Network using ring and linear topology were examined. Ryu SDN controller was considered, and 2 switches and 2 hosts were used as network topology, and it was observed that linear topology provides more bandwidth than ring topology under load. In another study, scholars [7] have integrated BitTorrent client in SDN using mesh topology to analyze its performance. Similar work was done in this paper [8] using ring topology where SDN outperforms under normal traffic load. Scholars [7] have used mesh topology in BitTorrent client to further verify their results and the outcomes were almost the same as mesh topology is not suitable for large number of users as the performance decreases under heavy load.

III. Problem Statement

Traditional networks are vulnerable and time worthy [9]. Multiple steps are required when an IT administrator needs to add or separate a single device in a traditional network. Initially, he will have to setupdifferent devices manually (firewalls,routers, switches) on a basis of device-by-device. The next step is using device-level administration mechanism to update various configuration settings, such as VLANs, ACLs and Quality of Service. This type of layout approach makes it much more difficult for a proprietor to establish a uniform set of policies also there are many restrictions in the traditional networks which needs to be overcome to meet today's current requirements. Bandwidth is one of the major elements that furnish the majority of network application implementation [10]. In any specific network system, there are basically many forms of application running on it contemporaneously. Application performance is certainly overdone by network circumstances. Nowadays, there are many smart applications that requires much higher bandwidth to facilitate robust communication and the traditional networks does not meet the requirements of such applications therefore the SDN was introduced to fulfil the requirements of such applications.

The currently deployed Mehran UET network as shown in Fig.3 is too complex and costly. Many problems occurred in this traditional network of the University such as the increasing capacity of traffic will slow down the overall network speed and performance of the whole network systems. One more problem with the network devices such as routers and switches, as they are expensive. As the switches and routers already programmed by the vendors, as they stopped working in the traditional network then the only solution is that replace the hardware (switches or routers). In SDN we do not need to replace the hardware on daily basis just change the code (program) in main SDN controller. Hence, the traffic moves on our desired choice.

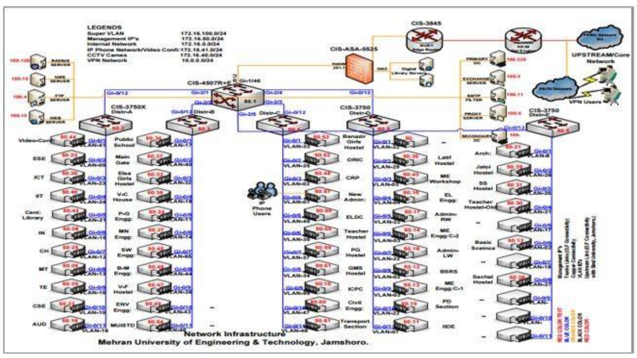


Figure 3: Current Network Infrastructure of Mehran UET, Jamshoro, Pakistan

IV. Aims and Objectives

The focus of this paper is two-fold. Firstly, we will analyze the performance of traditional networks and software-defined networks (SDN) using various topologies. For SDN, different controllers will be examined, and we will generate traffic in all scenarios to measure real world like performance. Finally, we will propose redundant network model for faculty of Electronics, Electrical & Computer Engineering (FEECE) of Mehran UET, Jamshoro, Pakistan using SDN and analyze its performance with current network model which is based on traditional network.

V. Experimental Method

The experiments of traditional networks were run in GNS-3 and Packet tracer software using windows 10 and experiments of software defined networks were simulated in Mininet using Linux OS on VMware workstation. Wireshark was used to capture packets in both networks. The Open Daylight [11], Floodlight [12], Beacon [13], Pox [14] and OpenFlow [15] controllers for SDN are considered in this paper. Five network topologies are used including proposed redundant network model for faculty of Electronics, Electrical & Computer Engineering (FEECE) of Mehran UET, Jamshoro, Pakistan, and these are explained below.

Star topology shown in Fig.4 using SDN network consists of single OpenFlow switch connected to multiple hosts. The OpenFlow switch is connected to OpenFlow controller through secure channel. Star topology in traditional network has single switch connected to multiple hosts but without any controller. In this topology, 8 hosts are taken that are connected to a single switch.

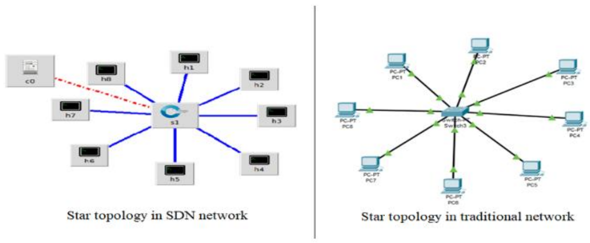


Figure 4: Star Topology of SDN/Traditional Network

In linear topology, number of switches are equal to number of hosts. It means that each switchis connected with their particular host. In this topology, 8 hosts are used that are connected to 8 switches in both networks. This topology is shown in Fig.5.

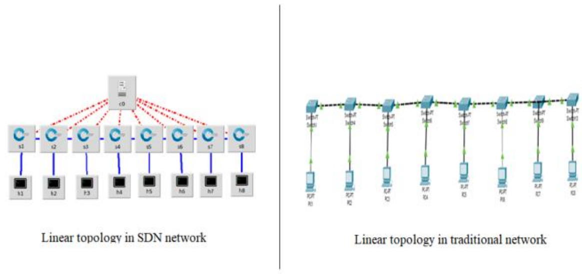


Figure 5: Linear Topology of SDN/Traditional Network

Fig.6 shows the ring topology. It contains 8 switches and 8 hosts, and every switch is connected in numeric series. Hence, switch2 is connected to switch1 and switch3 and switch1 is connected to switch8. Each switch is associated to a host. The Ring topology is the only topology used in this paper that contains multiple path or loops.

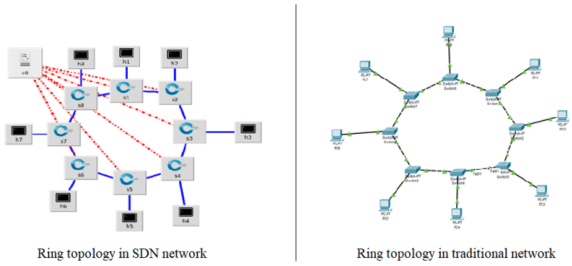


Figure 6: Ring Topology of SDN/Traditional Network

In tree topology, the switches are organized in binary layout in such a way that switch1 is the source node of tree topology and the leaf nodes are switch4 to switch7 as shown in fig.7. In this topology, 7 switches are used that are linked with 8 hosts. Each leaf node is linked with two hosts in order so that switch4 is linked to host1 and host2, and switch7 is linked to host7 and host8.

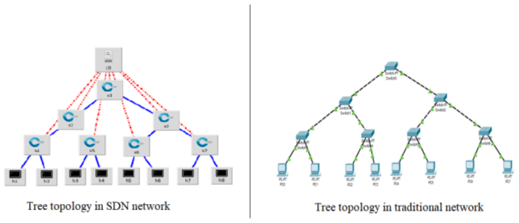


Figure 7: Tree Topology in SDN/Traditional Network

Finally, the redundant model of FEECE Faculty of Mehran UET, Jamshoro, Pakistan is proposed as shown in fig.8. This custom topology contains a single FEECE faculty controller and 7 open flow switches including one FEECE faculty switch. Every department has an open flow switch which has a two links for more redundancy, availability and connectivity for the network access. The FEECE Faculty Switch is directly connected with FEECE faculty controller and has 6 links with their departments including BM (biomedical dept.), TL (telecommunication dept.), ES (electronics dept.), SW (software dept.), CS (computer system dept.), EL (electrical dept.) respectively. This will give a high level of data rate and high level of security using security algorithms at FEECE faculty controller.

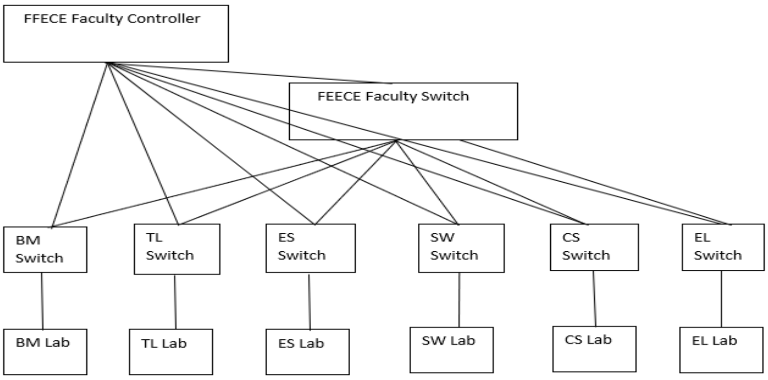


Figure 8: Proposed model of FEECE Faculty of Mehran UET, Jamshoro, Pakistan using SDN

VI. Performance Results

The experiments are done in two phases. In simulation 1, performance of traditional and SDN networks are analyzed using star, linear, ring and tree topologies. Three SDN controllers open daylight, floodlight and SDN default controller (OpenFlow) which is built-in to Mininet are considered. Controllers like Beacon and Pox does not work on the topologies that has more than one path [3]. In simulation 2, the performance of proposed model of FEECE faculty is analyzed with current model which is based on traditional network. We have generated network traffic with high load to examine the network performance of the FEECE faculty.

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A. Simulation I

The result in Fig.9 was conducted which shows maximum throughput of a network in a topology. This parameter measures how much data can be transmitted from source to destination. Tree topology in SDN network using floodlight controller has highest throughput of 25 Gigabits per second (Gbps) compared to tree topology in traditional network which is around 6 Gigabits per second (Gbps). Open Daylight provides a greater throughput with topologies that do not have a multiple paths or loops. In this case, only ring topology have multiple paths and maximum throughput in ring topology using open daylight controller is 0.2 Gbps.

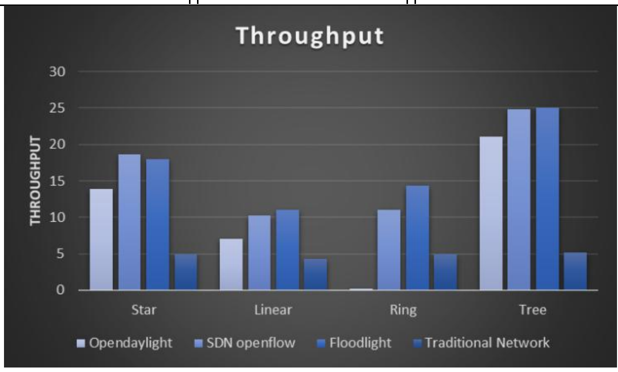

Figure 9: Throughput analysis of SDN/Traditional network in all topologies

Round-Trip Time (RTT) was analyzed in four topologies of SDN and Traditional networks. This parameter measures the total time for the packets to reach from source to destination. In this case, 500 packets were transmitted, and average and maximum round trip time was measured. The results of the experiments are shown in Table 1 and Table 2. The average RTT in floodlight is lower than other controllers and the average RTT in traditional network is higher in every topology. Hence, when Floodlight controller decides the path, thenthe RTT is much smaller. Though, the maximum RTT in Open Daylight controller is smaller than with Floodlight controller using tree topology. However, the maximum RTT in traditional networks is noticeably higher in all topologies. Packet loss is one of the downsides of Open Daylight. During the simulation,135 packets were lost out of 500, which is 27% of packet loss.

	Star	Linear	Ring	Tree
OpenFlow controller RTT avg.	4	5	3	2
Open Daylight RTT avg.	4.6	4.8	3.988	3.5
Floodlight RTT avg.	2.56	3	2.21	1.94
Traditional RTT avg.	22	45	50	36.5

Table 1: Average Round-Trip Time of SDN/Traditional network in all topologies

	Star	Linear	Ring	Tree
OpenFlow controller RTT max.	60	75	50	40.3
Open Daylight RTT max.	80	79	56	40
Floodlight RTT max.	58	70	50	42
Traditional RTT max.	103	200	180	123

Table 2: Maximum Round-Trip Time of SDN/Traditional network in all topologies

Maximum bandwidth was analyzed in SDN and Traditional network using four topologies and results are shown in Fig.10. This parameter identifies maximum amount of data that can be transmitted from source to destination. Tree topology in SDN network using floodlight controller has highest bandwidth of 29.87 Gbps compared to the tree topology of traditional network that has 12 Gbps. Maximum bandwidth in ring topology using Open Daylight is 0.34 Gbps because this controller is not ideal for topologies having more than one path. Maximum bandwidth in traditional network is less in all topologies.

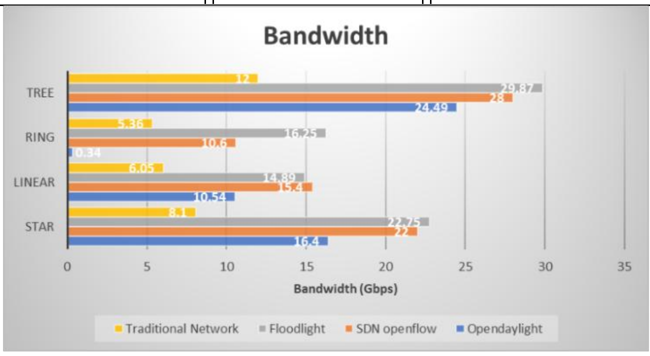

Figure 10: Bandwidth analysis of SDN/Traditional network in all topologies

Initial packet time results are given in Fig.11. It is the time taken for the first packet to transmit successfully to the desired destination. Open Daylight takes too long to transform to the ring topology as shown below because the topology contains more than one path. Although Open Daylight can operate on the topologies that has more than one path, it is not as ideal to the topologies like ring topology. In traditional network, initial packet time is higher in all topologies and in SDN network using floodlight controller in star topology, initial packet time is very low because it uses a single switch.

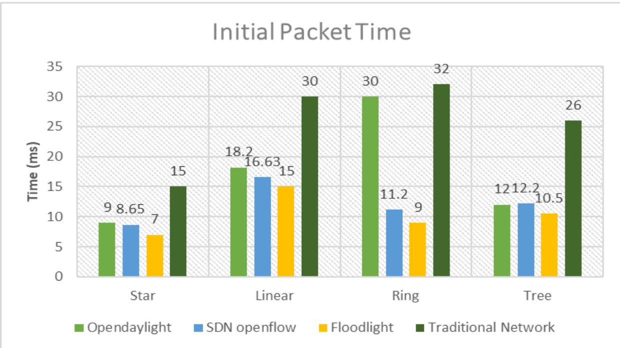

Figure 11: Initial Packet Time of SDN/Traditional network in all topologies

After analyzing the above results, it is observed that SDN networks can fulfill the requirements of today's smart applications that requires high bandwidth to operate. SDN networks with floodlight controller in tree topology gives better overall performance than other networks.

B. Simulation II

In this part, performance of FEECE faculty of Mehran UET is analyzed. Two network models are considered, one is based on traditional network which is currently deployed in Mehran UET and other is the proposed redundant model of FEECE faculty which is based on SDN network as it was shown in Fig.8. Based on the results in simulation I, the proposed model is using floodlight controller and it is designed in tree topology.

Throughput is an important parameter in networking, it gives approximately overall performance of a network. We have observed the throughput over time of FEECE faculty as they generate traffic requests per seconds. As the time increases throughput will also increase in SDN than the traditional network as shown in Fig.12.

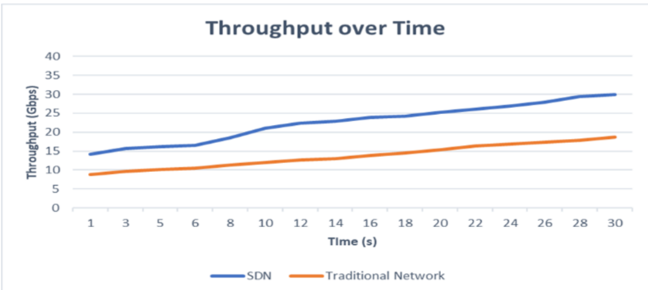

Figure 12: Throughput of FEECE faculty in SDN and Traditional Network

The bits are more corrupted in the traditional network than the SDN network as shown in Fig.13. As the no: of bits increases more bits are corrupted in traditional network than SDN network. SDN network model gives a better performance than the traditional network model.

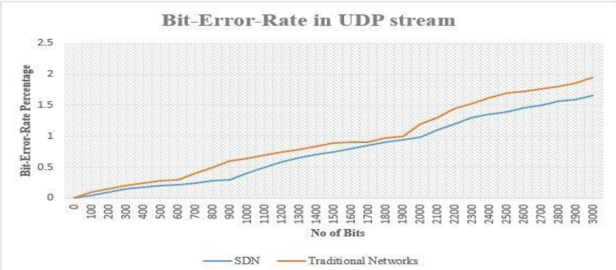

Figure 13: Bit-Error-Rate of FEECE faculty in SDN and Traditional Network

Initial packet time of FEECE faculty is analyzed in Fig.14. From the results, traditional model has higher initial time than SDN. 14ms in traditional network vs 6.14ms in SDN network.

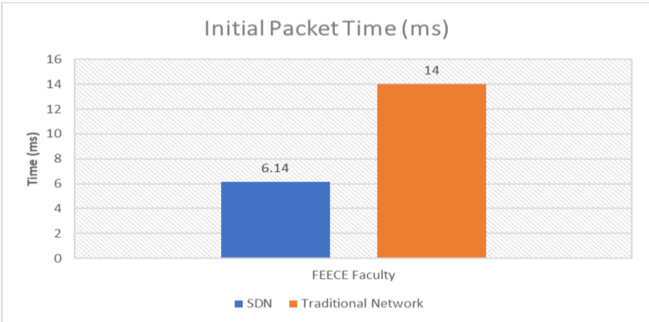

Figure 14: Initial Packet Time of FEECE faculty in SDN and Traditional Network

Throughput is maximum when latency is minimum in the network. TCP throughput vs latency of FEECE can be observed in Fig.15. The throughput of SDN slowly decreases as compared to that of the traditional network's throughput.

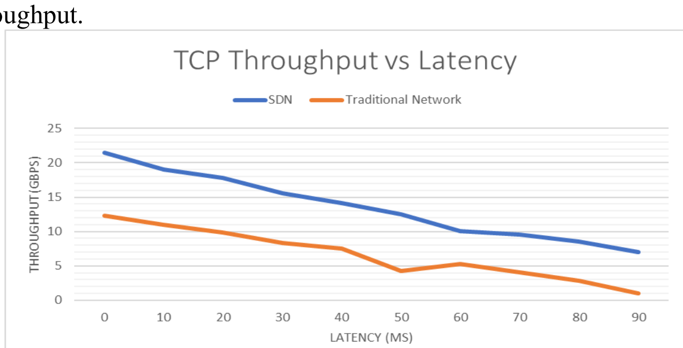

Figure 15: Throughput vs Latency of FEECE faculty in SDN and Traditional Network

TCP bandwidth (Gbps) is observed with respect to the no: of users. The bandwidth (data rate) of FEECE in SDN network is increasing as no: of users are increasing but it is increasing rapidly than traditional model as shown in Fig.16.

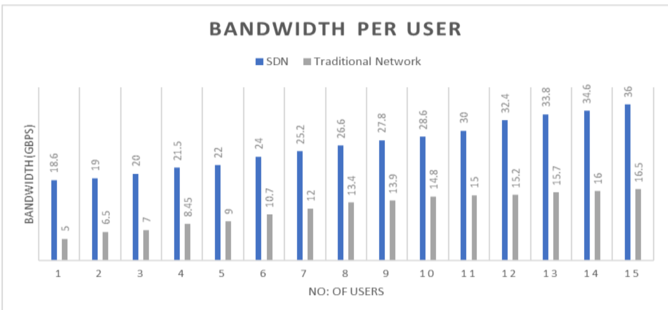

Figure 16: Bandwidth of FEECE faculty in SDN and Traditional Network

It is observed that if 1 thousand packets of equal length in both traditional and SDN network of FEECE faculty will be send through TCP stream than from Fig.17, it is clearly seen that RTT is maximum in the traditional network to that of the SDN.

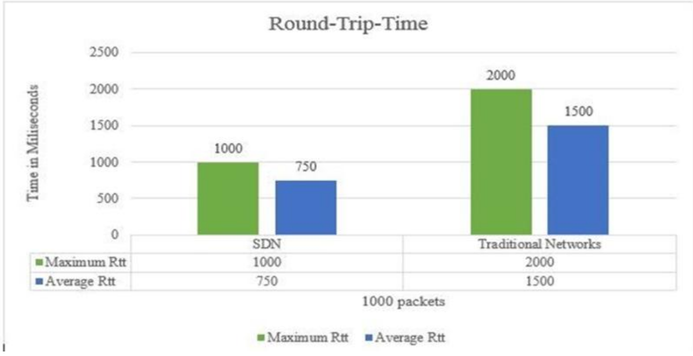

Figure 17: Round-Trip-Time of FEECE faculty in SDN and Traditional Network

VII. CONCLUSION

In this paper, we have analyzed the performance of SDN and Traditional Network. Four topologies were analyzed with different parameters and different SDN controllers were examined. It was observed that Floodlight SDN controller using tree topology is more adequate to the network and is far better than traditional networks. In this paper, we have also proposed a redundant network model for the faculty of Electronics, Electrical & Computer Engineering (FEECE) of Mehran UET, Jamshoro, Pakistan. Two redundant models for the faculty were analyzed in which one was based on the traditional networking and second one (proposed model) was based on the software defined networking. We have analyzed and observed both models with different parameters of network performance. Finally, it was observed that the SDN redundant model is best alternative to achieve high network performance and it is very cheaper than the traditional redundant model. SDN model is a software-based model i.e. without changing the hardware and Python is the most popular language in this respect. The SDN model also gives a centralized Administrative operation on the network.

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