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Optimized Network Topology for e-Learning Zone

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***Abstract*—In the 21st century in any organization, networking technology is critical in its day-to-day operations. In an academic institution, administrators explore this technology for an efficient way of transferring knowledge to students. They acquire latest trends of networking equipment to ensure the goal is being met. One of the challenges of the network designer is to come up with an efficient network having desirable performance.**

The objective of this research is to develop an optimization-based design framework for e-learning zone so that optimal performance would be achieved based on throughput. In particular, the first stage of this research is a network logical topology design for an efficient and robust connection of communication devices using Cisco Packet Tracer (PT) in which TCP was examined and analyzed. In this stage, the network performance based on throughput was determined by employing Little's Law. The second stage is an optimal performance design based on TCP/IP socket buffer length using JPerf for the topology obtained in the first stage.

The network performance of star and hybrid star topologies having 5, 10 and 15 communication devices was investigated. Simulation results based on TCP validates the fact that the hybrid star topology produced higher throughput than the star topology. As a result, the optimized network topology was hybrid star topology. The study revealed that the optimal performance of the hybrid star topology in the real-world scenario having a TCP/IP socket buffer length of 1 MB produced the highest throughput of 94570 Kbps.

***Index Terms*—Cisco Packet Tracer, network performance, network topology, throughput, TCP.**

I. INTRODUCTION

Networks are playing an important role in modern society, as they applied to every domain in daily life from entertainment to commerce, banking, and industry [1]. In the academe, the application of local area network is a necessity in the dissemination of valuable information to students.

In an educational institution, the application of the latest networking technology is a must. Network users often complain of its poor performance. This research contributes to the process of optimizing performance of e-Learning Zone network topology.

A network is a complex mix of applications, communications protocols and link technologies, traffic flows and routing algorithms [2]. Transport Control Protocol is one of those communications protocols that will be the focus of this research. It provides a reliable end-to-end connection. It is the protocol relying on major Internet applications.

The performance of TCP affects the performance of the network. The LAN topological problem could be formalized as a multi-objective optimization problem. It is a procedure in search of the best topology that can maximize or minimize some performance criterions at the same time under the constraints from the real world [5].

TCP is the dominant transport protocol used in the Internet applications. It includes the world-wide web, peer to peer file sharing and media streaming [6] and its performance fundamentally governing the performance of the internet applications [7]. In fact, more than 90% of the generated traffic is controlled by TCP whereas User Datagram Protocol (UDP) approximately manages the rest [8].

The objective of this research is to develop an optimization-based design framework for e-learning zone so that its optimal performance would be achieved based on throughput. In particular, the first stage of this research is a network logical topology design for an efficient and robust connection of communication devices using Cisco Packet Tracer in which TCP was examined and analyzed. The second stage is an optimal performance design based on TCP/IP socket buffer length for the topology obtained in the first stage.

II. REVIEW OF RELATED LITERATURE AND STUDIES

Over the last decade, from relatively static pages to websites rich with interactive media content, there were related works or studies quantifying and analyzing the evolution of web content. It affected the associated network traffic that led to the updated traffic models and more accurate web traffic simulations for testing new protocols and devices. B. Newton, K. Jeffay, and J. Aikat [9] analyzed the TCP/IP headers in packet traces collected at various times over 13 years on the link that connect the University of North Carolina at Chapel Hill (UNC) to its ISP. They proposed a novel method for segmenting web traffic into activity sections to obtain comparable higher level statistics. S. Akhtar, A. Francini, D. Robinson, and R. Sharpe [10] tested AQM techniques on their ability to influence end-user Quality of Service (QoE), especially HTTP Adaptive Streaming (HAS) based video traffic on fixed access networks using ns-2 for building simulation scenarios for realistic internet traffic. These studies were concerned with web traffic but do not have examination traces of individual connections.

The performance of network topology was studied using simulation techniques. Magoni [11] focused on the architecture of network manipulator (nem) capable of creating realistic Internet-like topologies and can check on thorough topology analysis. X. Li, H. Bo, L. Haixia, and Y. Mingqiang [12] studied topology control that affects other significant performances for both static and dynamic scenarios in ns-2 for the ad hoc wireless network. Zhang and Luo [13] simulated the delay and throughput of the network performance parameters of MAC layer through changing the node size, network load, and ACK mode by using opnet

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network simulation software in non-beacon enabled transmission mode. W. Li, X. Wang and Q. Zhu [14] analyzed the topology and the clusters for a localized social network in SINA Weibo and tried to find whether they have small world properties using Gephi . W. Zhang, W. Wu, L. Zuo, and X. Peng [15] analyzed the buffer depth of 2-dimension mesh topology NoC with odd-even routing algorithm based on NoC interconnect routing and application modeling (NIRGAM) simulator. In this research, PT was used in the simulation of star and hybrid star network topology.

Xie and Pan [16] analyzed the topology of the mesh of large-scale hybrid P2P network. They presented two power-laws concerning the mesh topology. They examined the topology properties of the highly dynamic architecture of the current Gnutella network. They provided one empirical law concerning the tree size. However, the analysis of P2P network topology does not involve any protocol. H. Zhang, C. Leung, and G. Raikandalia [17] proposed a novel hybrid topology for multi-agent systems. They compared the performance of this topology with two other common agent network topologies within the new multi-agent framework, agent-based open connectivity for DSS (AOCD). H. Zhang, C. Leung, and G. Raikandalia estimated topology performance based on transmission time for a set of requests, waiting time for processing requests and memory consumption for storing agent information. However, the monitored network parameters are different. In this research, the TCP/IP socket buffer length was the basis for monitoring the performance of two different topologies.

TCP Variants

In wireless networks, ns-2 based simulation analysis of TCP-Tahoe, TCP-Reno, TCP-New Reno, TCP-SACK, TCP-Veno, TCP-Westwood, TCP-Westwood New Reno, and TCP-New Jersey was described [18]. S. Waghmare, A. Parab, P. Nikose and S. Bhosale [19] analyzed the performance of TCP variants, which were designed to improve performance in the wireless networks. An ns-2 based simulation analysis of TCP Tahoe, TCP Reno, TCP NewReno, TCP Sack, TCP Vegas, and TCP New Jersey was done. Bhanumathi and Dhanasekaran [20] evaluated TCP variants in ad hoc network environment using NS-2.29 and resulted in choosing the best TCP for a particular application. A. Urke, L. Braten and K. Ovsthus [21] assessed the performance of widely deployed TCP variants in military tactical networks, a hybrid network of satellite, and radio links. The network topology and protocol studied by Henna, Waghmare, A. Parab, P. Nikose, and S. Bhosale , A. Urke, L. Braten, and K. Ovsthus and Bhanumathi and Dhanasekaran were different from this research. In this study, the performance of TCP was monitored in a wired network.

TCP Optimization

There are also studies to solve TCP problems of HAPs network. An optimized TCP for HAPs network was proposed consisting of rapid congestion notification, reason of packet loss recognition and traffic oriented congestion control [22]. The goals of optimizing TCP by Weiqiang, Qin Yu, and Siyao are the same with this research but the focus of the network is different. In this research, e-learning zone was the focus of study. H. Xie, R. Pazzi, and A. Boukerche [23] analyzed and modelled the factors that affect the TCP throughput in the lower layers . They solved the optimization problem by formulating TCP performance as a Markov Decision Process (MDP) using NS-2 over wireless networks. H. Xie, R. Pazzi, and A. Boukerche goals of optimizing TCP are the same with this study, but the simulators are different. In this research, PT was used instead.

B. Blaszczyszyn, M. Jovanovicy, and M. K. Karry [24] defined a global user mean throughput in the cellular network. They proved that it was equal to the ratio of mean traffic demand to the mean number of users in the steady state of the “typical cell” of the network. In this research, Little’s Law was employed in the determination of the network performance based on throughput.

Performance Analysis Based on Throughput

This analysis is closely related to Mazalan, et al. [25] research on TCP/IP socket buffer length or buffer size. It is the size of memory that allocates for the traffic buffers being sent and receive in Local Area Network (LAN) and Wide Area Network (WAN) clustering with the use of JPerf. By controlling the buffer size, TCP can manage the application network performance. They analyzed the throughput performance of the measured buffering. The goals of Mazalan, et al. are the same as the goal of this research but the focus of network analysis is different. Mazadan, et al. dealt in LAN and WAN. In this research, the use of JPerf to optimize network performance of an e-learning zone is emphasized.

The Communications Network Modelling Tool (CNMT) which permit users to model and analyze communications network and to assess their performance [26] is one example of this research. However, this software does not consider the examination of any internetworking protocols. There are more than forty leading tools being used in the field of network performance analysis, modeling, and simulation. It includes Q+, ATOMS, PAT, MyPAL, PANACEA, Q2 (Q SQUARED), PFM, RESQME, SES, ALTIA, BONES, SCRIBE, OPNET, COMNET III, MIND, INOS, MAKE Systems, WANDL, TES Tool, QUEUE, M/G/IM+1, GI/MM+I, CAPER, ATT Network Flight Simulator, WITNESS, ECLIPSE, STELLA/I, Think, CRYSTALL BALL/PowerSim, MOPTsim, SIMNET II, CSIM, NSIM, EXAMS, TrafCalc, TRAFLIB, Unfit II, Modline, Optimal Networks, Item 95, Synergist/Quintessential/Autone, JADE, Concord and INDT [27].

Petcu and et al. [28] described PT as a powerful visualization and simulation tool that allows students to design, build and troubleshoot networks in a safe environment. PT is a comprehensive simulation, visualization, collaboration and micro-world authoring tool for teaching networking concepts [29]. A network simulation tool may provide several additional benefits such as visual expression of network topology, reusability of existing network, simulation model, and editing the configuration of the network. Therefore, users can analyze the simulation result more accurately and rapidly. These additional functions make the network simulation tool more useful and suitable for analysis and network performance [30]. In this research study, PT was used for the design and simulation of a network topology for the e-learning zone.

III. METHODOLOGY

The virtual and actual analyses involve quantifiable data that require numerical and statistical explanations. Hence, quantitative method of research is used in this study.

A. Virtual Analysis and Evaluation of Network Performance of Star and Hybrid Star Network Topologies based on TCP

PT was utilized in the virtual analysis and evaluation of the TCP performance of star and hybrid star network topologies.

A.1 Star Network Topology

A logical connection of Star Network Topology was established having five (5), ten (10), and fifteen (15) communication devices.

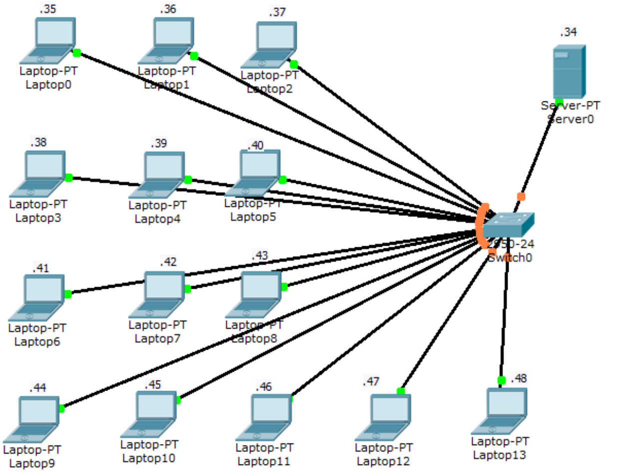


Figure 1. Star Network Topology Having Fifteen (15) Communication Devices

As shown in Fig. 1, fourteen (14) laptops and a server were connected to a 24-port Cisco 2950 switch. Straight through cables were used in the communication between the laptop and the switch and also between the server and the switch. Each of the laptops, together with the server, was configured with distinct internet protocol addresses. The switch was configured to have a rated speed of 100 Mbps. The laptops and the server were also configured to have a rated speed of 100 Mbps. To make sure that there was communication between the networking devices, pinging the server from each of the laptops was made successfully.

A.2 Hybrid Star Network Topology

A logical connection of a hybrid star network was established having five (5), ten (10), and fifteen (15) communication devices.

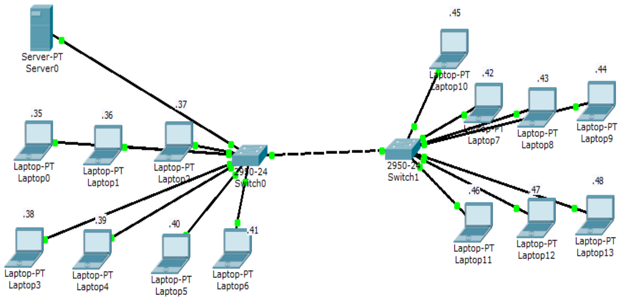


Figure 2. Star Hybrid Topology Having Fifteen (15) Communication Devices

As shown in Fig. 2, seven (7) laptops and a server were connected to a 24-port Cisco 2950 switch. This 24-port Cisco 2950 switch was then connected to another 24-port Cisco 2950 switch where seven (7) more laptops were connected.

Straight through cables were used in the communication between the laptop and the switch and also between the server and the switch. Each of the laptops, together with the server, was configured with the distinct internet protocol addresses. The switch was configured to have a rated speed of 100 Mbps. The laptops and the server were also configured to have a rated speed of 100 Mbps. To make sure that there was communication between the networking devices, pinging the server from each of the laptops was made successfully.

In the simulation mode of PT, TCP was filtered for analysis in this research. Each of the laptops was then configured to connect to the server's http. The simulation was carried out, and then the TCP packet traces were collected and analyzed. The information gathered on the TCP packet trace included the source internet protocol address, source port, destination internet protocol address, destination port, the sequence number, the acknowledgement number, the window size each device was capable of accepting, and the length of the packet.

The response time for each client on the network was taken into account and tabulated. The throughput or the actual bandwidth of each client was computed using (1)

$$\text{Throughput} = \text{response time} \times \text{rated speed} \qquad (1)$$

By employing Little's Law, the throughput of the network was calculated by taking the average of the throughput of each of the clients in the network.

Finally, the network performance based on the throughput of the star network topology and hybrid star network topology were compared. The one with the higher throughput was considered as the optimized network topology for use in the e-learning zone.

B.Actual Analysis and Evaluation of the Performance of an Optimized Network Topology Based on TCP/IP Socket Buffer Length

Having the optimized network topology, the determination of optimal network performance was carried out in an actual scenario by allowing the chemical engineering students to have access to the server.

B.1 Design of Hybrid Star Network Topology

The laptops were connected to two (2) Cisco Catalyst 2560 series using straight through cables. Each of the workstations was configured with an internet protocol address and subnet mask. The server used Intel i5-2410 as the central processing unit. The hardware specification used in the e-Learning Zone would contribute to the performance of the wired network itself. Having processors and switches with high performance, e-learning zone performs better. Tables I and II show the processors and switches specifications that were used for the e-learning zone.

Table I. Specification of Processors

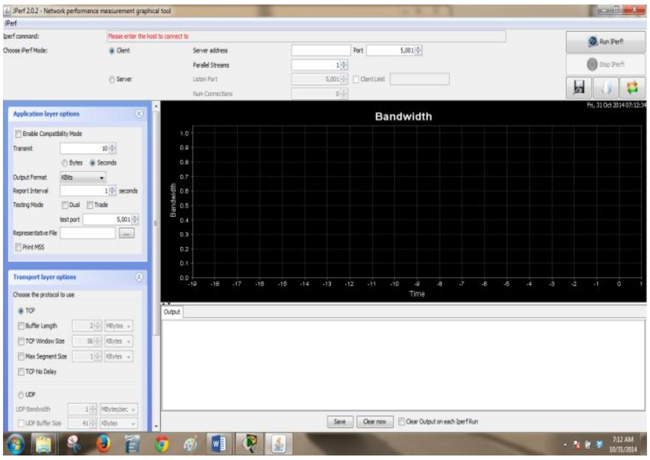
Component	Processor	Max Memory, GB	Cache MB	Cor es	Memory Channel	Memory Bandwidth GBps
Server	Intel i5-2410M	16	3	2	2	21.3
Client	Intel i5-3230M	32	3	2	2	25.6

Table II. Specification of Switches

Switches : Cisco Catalyst 2960 Series	
Standards	IEEE 802.3 at compliant
Ports x Speed	48 Gigabit 10/100/1000
Power Saving	Cable connected detection Cable length detection
Minimum Saving Requirements	Connected devices need Ethernet connectivity and Ethernet cables
Memory Bandwidth	21 GB/s

B.2 Measurement of Optimal Network Performance Using JPerf

JPerf, as shown in Fig. 3, was used to determine the performance of the network with optimized network topology based on socket buffer length. The transmit time was set to 20 seconds. A workstation having JPerf installed was set in client mode together with the internet protocol address of the server. JPerf was also installed on the server and was set in server mode. The tests were run in three trials having buffer lengths of 1 KB, 4 KB, 16 KB, 64 KB, 256 KB, 1 MB, 4 MB, and 16 MB. The data were collected and analyzed.



JPerf 2.0.2 - Network performance measurement graphical tool

Iperf command: Please enter the host to connect to

Choose iPerf Mode: ● Client ○ Server

Port 5,001

Parallel Streams 1

Listen Port 5,001

☐ Client Limit

Num Connections 0

Application layer options

☐ Enable Compatibility Mode

Transmit 10 ○ Bytes ● Seconds

Output Format KBits

Report Interval 1 seconds

Testing Mode ☐ Dual ☐ Trade

test port 5,001

☐ Print MSS

Transport layer options

Choose the protocol to use ● TCP

☐ Buffer Length 2 MBytes

☐ TCP Window Size 56 KBytes

☐ Max Segment Size 1 KBytes

☐ TCP No Delay

○ UDP

UDP Bandwidth 1 MBytes/sec

☐ UDP Buffer Size 41 KBytes

Figure 3.JPerf Network Performance Tool

IV. RESULTS AND DISCUSSION

A. Results of the Virtual Analysis and Evaluation of Network Performance of Star and Hybrid Star Network Topologies based on TCP

A.1 Results of the Virtual Analysis and Evaluation of TCP Performance of Star Network Topology

Using PT, the TCP packet traces of the star network topology having five (5), ten (10), and fifteen (15) communication devices were collected. Table III shows the traces for fifteen (15) communication devices.

Table III. TCP Packet Traces in Star Topology Having Fifteen (15) Communication Devices

Time s	Src Addr	Src Port	Dest Addr	Dest Port	SEQ	ACK	WIN	len
0	.35	1026	.34	80	0	0	65535	24
0	.36	1025	.34	80	0	0	65535	24
0	.37	1025	.34	80	0	0	65535	24
0	.38	1025	.34	80	0	0	65535	24
0	.39	1025	.34	80	0	0	65535	24
0	.40	1025	.34	80	0	0	65535	24
0	.41	1025	.34	80	0	0	65535	24
0	.42	1025	.34	80	0	0	65535	24
0	.43	1025	.34	80	0	0	65535	24
0	.44	1025	.34	80	0	0	65535	24
0	.45	1025	.34	80	0	0	65535	24
0	.46	1025	.34	80	0	0	65535	24
0	.47	1025	.34	80	0	0	65535	24
0	.48	1025	.34	80	0	0	65535	24
0.002	.34	80	.35	1025	0	1	16384	24
0.003	.34	80	.36	1025	0	1	16384	24
0.004	.34	80	.37	1025	0	1	16384	24
0.004	.35	1025	.34	80	1	1		20
0.005	.34	80	.38	1025	0	1	16384	24
0.005	.36	1025	.34	80	1	1		20
0.006	.34	80	.39	1025	0	1	16384	24
0.006	.37	1025	.34	80	1	1		20
0.007	.34	80	.40	1025	0	1	16384	24
0.007	.38	1025	.34	80	1	1		20
0.008	.34	80	.41	1025	0	1	16384	24
0.008	.39	1025	.34	80	1	1		20
0.009	.34	80	.42	1025	0	1	16384	24
0.009	.40	1025	.34	80	1	1		20
0.010	.34	80	.43	1025	0	1	16384	24
0.010	.41	1025	.34	80	1	1		20
0.011	.34	80	.44	1025	0	1	16384	24
0.011	.42	1025	.34	80	1	1		20
0.012	.34	80	.45	1025	0	1	16384	24
0.012	.43	1025	.34	80	1	1		20
0.013	.34	80	.46	1025	0	1	16384	24
0.013	.44	1025	.34	80	1	1		20
0.014	.34	80	.47	1025	0	1	16384	24
0.014	.45	1025	.34	80	1	1		20
0.015	.34	80	.48	1025	0	1	16384	24
0.016	.47	1025	.34	80	1	1		20
0.017	.48	1025	.34	80	1	1		20

The response time, the throughput of each workstation, and average throughput in a star network topology having five (5), ten (10), and fifteen (15) communication devices were determined. The results are shown in Tables IV, V, and VI, respectively.

Table IV. Response Time, Throughput of each Workstation, and Average Throughput in a Star Network Topology having Five (5) Communication Devices

IP Address	Response Time, s	Throughput, Mb
10.3.21.35	0.004	0.4
10.3.21.36	0.005	0.5
10.3.21.37	0.006	0.6
10.3.21.38	0.007	0.7
Average Throughput		0.55

Table V. Response Time, Throughput of each Workstation, and Average Throughput in a Star Network Topology having Ten (10) Communication Devices

IP Address	Response Time, s	Throughput, Mb
10.3.21.35	0.004	0.4
10.3.21.36	0.005	0.5
10.3.21.37	0.006	0.6
10.3.21.38	0.007	0.7
10.3.21.39	0.008	0.8
10.3.21.40	0.009	0.9
10.3.21.41	0.010	1.0
10.3.21.42	0.011	1.1
10.3.21.43	0.012	1.2
Average Throughput		0.8

Table VI. Response Time, Throughput of each Workstation, and Average Throughput in a Star Network Topology having Fifteen (15) Communication Devices

IP Address	Response Time, s	Throughput, Mb
10.3.21.35	0.004	0.4
10.3.21.36	0.005	0.5
10.3.21.37	0.006	0.6
10.3.21.38	0.007	0.7
10.3.21.39	0.008	0.8
10.3.21.40	0.009	0.9
10.3.21.41	0.010	1.0
10.3.21.42	0.011	1.1
10.3.21.43	0.012	1.2
10.3.21.44	0.013	1.3
10.3.21.45	0.014	1.4
10.3.21.46	0.015	1.5
10.3.21.47	0.016	1.6
10.3.21.48	0.017	1.7
Average Throughput		1.05

A.2 Results of the Virtual Analysis and Evaluation of TCP Performance of Hybrid Star Network Topology

Using Cisco Packet Tracer, the TCP packet traces of the hybrid star network topology having five (5), ten (10), and fifteen (15) communication devices were collected. Table VII shows the traces for fifteen (15) communication devices.

Table VII. TCP Packet Traces in Hybrid Star Topology Having Fifteen (15) Communication Devices

Time s	Src Addr	Src Port	Dest Addr	Dest Port	SEQ	ACK	WIN	len
0	.35	1026	.34	80	0	0	65535	24
0	.36	1025	.34	80	0	0	65535	24
0	.37	1025	.34	80	0	0	65535	24
0	.38	1025	.34	80	0	0	65535	24
0	.39	1025	.34	80	0	0	65535	24
0	.40	1025	.34	80	0	0	65535	24
0	.41	1025	.34	80	0	0	65535	24
0	.42	1025	.34	80	0	0	65535	24
0	.43	1025	.34	80	0	0	65535	24
0	.44	1025	.34	80	0	0	65535	24
0	.45	1025	.34	80	0	0	65535	24
0	.46	1025	.34	80	0	0	65535	24
0	.47	1025	.34	80	0	0	65535	24
0	.48	1025	.34	80	0	0	65535	24
0.002	.34	80	.35	1026	0	1	16384	24
0.007	.34	80	.36	1025	0	1	16384	24
0.013	.34	80	.37	1025	0	1	16384	24
0.014	.34	80	.38	1025	0	1	16384	24
0.015	.34	80	.39	1025	0	1	16384	24
0.016	.34	80	.40	1025	0	1	16384	24
0.018	.34	80	.41	1025	0	1	16384	24
0.019	.34	80	.42	1025	0	1	16384	24
0.020	.34	80	.43	1025	0	1	16384	24
0.021	.34	80	.44	1025	0	1	16384	24
0.022	.34	80	.45	1025	0	1	16384	24
0.023	.34	80	.46	1025	0	1	16384	24
0.024	.34	80	.47	1025	0	1	16384	24
0.025	.34	80	.48	1025	0	1	16384	24
0.034	.35	1026	.34	80	1	1		20
0.035	.36	1025	.34	80	1	1		20
0.036	.37	1025	.34	80	1	1		20
0.037	.38	1025	.34	80	1	1		20
0.044	.39	1025	.34	80	1	1		20
0.045	.40	1025	.34	80	1	1		20
0.046	.41	1025	.34	80	1	1		20
0.051	.42	1025	.34	80	1	1		20
0.052	.43	1025	.34	80	1	1		20
0.053	.44	1025	.34	80	1	1		20
0.054	.45	1025	.34	80	1	1		20
0.055	.46	1025	.34	80	1	1		20
0.056	.47	1025	.34	80	1	1		20
0.057	.48	1025	.34	80	1	1		20

The response time, the throughput of each workstation, and average throughput in a hybrid star network topology having five (5), ten (10), and fifteen (15) communication devices were determined. The results were shown in Tables VIII, IX, and X, respectively.

Table VIII. Response Time, Throughput of each Workstation and Average Throughput in a Hybrid Star Network Topology having Five (5) Communication Devices

IP Address	Response Time, s	Throughput, Mb
10.3.21.35	0.014	1.4
10.3.21.36	0.029	2.9
10.3.21.37	0.039	3.9
10.3.21.38	0.040	4.0
Average Throughput		3.05

Table IX. Response Time, Throughput of each Workstation, and Average Throughput in a Hybrid Star Network Topology having Ten (10) Communication Devices

IP Address	Response Time, s	Throughput, Mb
10.3.21.35	0.027	2.7
10.3.21.36	0.028	2.8
10.3.21.37	0.029	2.9
10.3.21.38	0.030	3.0
10.3.21.39	0.046	4.6
10.3.21.40	0.047	4.7
10.3.21.41	0.048	4.8
10.3.21.42	0.049	4.9
10.3.21.43	0.050	5.0
Average Throughput		3.93

Table X. Response Time, Throughput of each Workstation, and Average Throughput in a Hybrid Star Network Topology having Fifteen (15) Communication Devices

IP Address	Response Time, s	Throughput, Mb
10.3.21.35	0.034	3.4
10.3.21.36	0.035	3.5
10.3.21.37	0.036	3.6
10.3.21.38	0.037	3.7
10.3.21.39	0.044	4.4
10.3.21.40	0.045	4.5
10.3.21.41	0.046	4.6
10.3.21.42	0.051	5.1
10.3.21.43	0.052	5.2
10.3.21.44	0.053	5.3
10.3.21.45	0.054	5.4
10.3.21.46	0.055	5.5
10.3.21.47	0.056	5.6
10.3.21.48	0.057	5.7
Average Throughput		4.68

Using Table XI, the average throughput of star network topology having five (5) communication devices is 0.55 Mb while the average throughput of the hybrid star network topology is 3.05 Mb. The network topology that has better

TCP performance having five (5) communication devices is Hybrid Star Network Topology. The average throughput of star network topology having ten (10) communication devices is 0.80 Mb while the average throughput of hybrid star network topology is 3.93 Mb. The network topology that has better TCP performance having ten (10) communication devices is the Hybrid Star Network Topology. The average throughput of the star network topology having fifteen (15) communication devices is 1.05 Mb while the average throughput of hybrid star network topology is 4.68 Mb. The network topology that has better TCP performance having fifteen (15) communication devices is the Hybrid Star Network Topology.

Table XI. Comparison of the Average Throughput in Mb of the Five (5), Ten (10) and Fifteen (15) Communication Devices in Star and Hybrid Star Network

Number of Devices	Average Throughput, Mb	
	Star	Hybrid Star
5	0.55	3.05
10	0.80	3.93
15	1.05	4.68

B.Results of the Actual Analysis and Evaluation of the Performance of an Optimized Network Topology Based on TCP/IP Socket Buffer Length

For the first trial as shown in Table XII having the socket buffer length equal to 1 KB, the throughput was 38616 Kbps. The throughput increases as the buffer length was increased to 4 KB, 16 KB, 64 KB, 256 KB, and 1 MB having throughput values of 43391, 91094, 93471, 93495, and 94625 Kbps, respectively. The throughput then decreases as the buffer length was increased to 4 MB and 16 MB having throughput values of 94555 and 94286 Kbps, respectively. For the second and third trials as the buffer length increases from 1 KB to 1 MB, the throughput increases correspondingly and increasingly further the buffer length to 16 MB, the throughput decreases.

Table XII. Results of the JPerf Network Performance Analysis

Trial	1 KB	4 KB	16 KB	64 KB	256KB	1 MB	4 MB	16 MB
1	38616	43391	91094	93471	93495	94625	94555	94286
2	38442	42961	93497	93670	94227	94578	94413	94414
3	38661	43243	93471	93784	94601	94507	94606	94528
Average	38573	43198	92687	93642	94108	94570	94525	94409

Plotting the average throughput versus socket buffer length can be seen in Fig. 4. The values of the average throughput for the socket buffer length of 1 KB and 4 KB were not included. The values were way below the other values. It can be seen in Fig. 4 that the socket length that produced the maximum throughput was 1 MB.

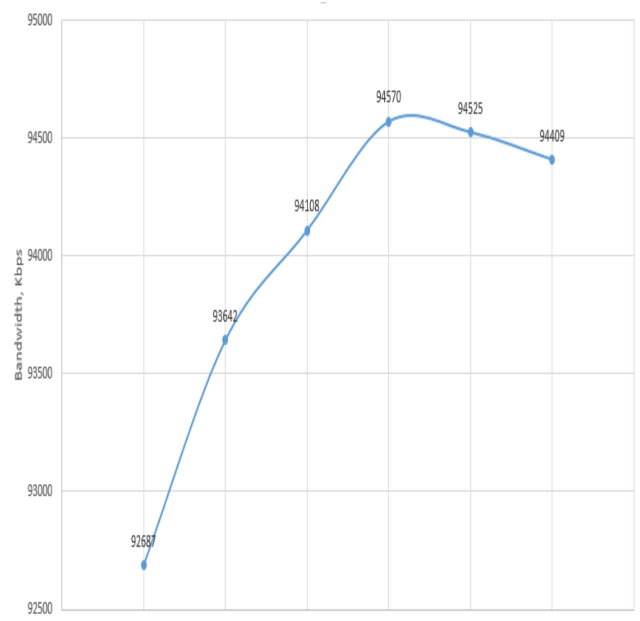


Figure 4. Average Throughput versus Socket Buffer Length

V. CONCLUSIONS AND RECOMMENDATION

As a result of the PT simulation, the hybrid star network topology was identified as the optimized network topology for e-learning zone. The addition of a networking switch decongested the network traffic. It produced several alternative paths for data movement. This hybrid star network topology produced higher throughput than the star network topology for all networks having five (5), ten (10), and fifteen (15) communication devices which were 3.05, 3.93, and 4.68 Mb, respectively.

Based on the JPerf network simulation, it showed that 1 MB of buffer length with a maximum throughput of 94570 Kbps produced the optimal network throughput of the hybrid star network topology. The value that is less than 1 MB can make the e-learning zone underutilized while the value greater than 1 MB would contribute to the delay of the e-learning zone because of the empty buffer that must be filled in. This value of buffer size proposed an optimization value for the server and clients to work efficiently in its data communication.

Therefore, network administrator of any organization should optimize its network infrastructure to achieve a well-designed client-server system by increasing the number of networking switches and adjusting the TCP/IP buffer size or length.

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