ENHANCEMENT OF ENTEPRISE NETWORK PERFORMANCE THROUGH VIRTUAL LOCAL AREA NETWORK IMPLEMENTATION: CASE STUDY AT UNIVERSITÉ LUMIÈRE DE BUJUMBURA, KININDO, BUJUMBURA, BURUNDI

BY

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A RESEARCH THESIS SUBMITTED TO THE DIRECTORATE OF HIGHER DEGREES AND RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN INFORMATION TECHNOLOGY OF KAMPALA INTERNATIONAL UNIVERSITY
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DECLARATION

I hereby declare that this submission is my work towards a Master's degree in Science of Information Technology and that to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the University, except where due acknowledgment/reference has been made to the work.

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APPROVAL

I have read and at this moment recommends the thesis titled an Enhancement of Enterprise Network Performance Through Virtual Local Area Network Implementation, in partial fulfillment of the requirements for the degree Master Of Science in Information Technology at Kampala International University.

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DEDICATION

I dedicate this piece of work to my father, my mother and my siblings whose supports gratly contributed to the fulfillment of this Research Thesis.

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All thanks go to the supremacy God, for blessing me with the knowledge of understandings and exceptional hope for which I am grateful to.

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ABSTRACT

This study was to enhance an enterprise network performance through virtual local area network implementation by simulating an existing local area network and rectifying it using virtual local area network at Université lumière de Bujumbura, in two different scenarios (existing LAN and new LAN with VLAN implementation). The enterprise network performance at the university was unsatisfactory due to unsegmented network that cause inconsistent and unreliable network. Therefore, the study had the following objectives: To investigate the user satisfaction of the enterprise network performance, to identify the drawbacks of existing enterprise network performance, to measure the existing enterprise network performance, to rectify the drawbacks of existing enterprise network using virtual local area network, to simulate and compare the new (virtual local area network) and existing (no virtual local area network) enterprise network performance. The first objective was used questionnaire for and the end users at ULB were not satisfied with the network performance while structured interview was used in the second objective and there was unsegmented network at Université lumière de Bujumbura; And also, riverbed modeler academic edition 17.5 (OPNET) was used to get simulation results, measure and compare the network performance for both scenarios (with and without virtual local area network) in the third, fourth and fifth objectives. In third objective enterprise network components with no virtual local area network were implemented into optimized network engineering tool (OPNET) and the fourth objective was a duplicated scenario with virtual local area networkimplementation. The OPNET simulation results illustrated in third and fourth objective the minimum, average and maximum statistic data for both global and object statistics for both new (virtual local area network) and existing enterprise network without Virtual local area network technology. The simulated results for the fifth objective were comparison for both scenarios with and without virtual local area network and virtual local area networks had better performance than no virtual local area network. The global statistics results showed that virtual local area network had lower traffic and response time compared to no virtual local area network due to a segmentation of single large broadcast domain into separate broadcast domains in order to reduce and control traffic sent and received on the network and also virtual local area networks improved bandwidth utilization, power, speed and security. Virtual local area network effectively improved the network performance of the existing local area network simulated in OPNET simulator at Université lumière de Bujumbura. The study recommended that Université lumière de Bujumbura and other universities should implement virtual local area network to improve enterprise network performance, since Virtual local area network can significantly enhance the network performance as well enforce network security.

ACRONYMS AND ABBREVIATIONS

ACL:	Access Control List
ARP:	Address Resolution Protocol
DHCP:	Dynamic Host Configuration Protocol
FDDI:	Fiber Distributed Data Interface
FTP:	File Transfer Protocol
HTTP:	Hypertext Transfer Protocol
HTTPS:	Hypertext Transfer Protocol Secure
ICT:	Information and Communications Technology
IEEE:	Institute Electrical and Electronics Engineers
IP:	Internet Protocol
ISL:	Inter-Switch Link
ISP:	Internet Service Provider
ITU:	International Telecommunication Union
LAN:	Local Area Network
MAC:	Media Access Control Address
NO_VLAN:	No Virtual Local Area Network
NOC:	Network Operations Center
OPNET:	Optimized Network Engineering Tool
RIP:	Routing Information Protocol
SPSS:	Statistical Package for the Social Sciences
TCP :	Transmission Control Protocol
ULB :	Université Lumière De Bujumbura
VLAN:	Virtual Local Area Network
VLT:	Virtual Local Area Network Trunk

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CHAPTER ONE
INTRODUCTION

1.0 Introduction

This chapter covers the background, problem statement, objectives, research questions, scope of the study and significance.

1.1 Background of the Study

In modern and global world, the importance and added values provided by Network infrastructure is evident whether it is for government entities, business enterprises or educational institutions particularly universities (Yoloye, 2015). It contributes to achieve important goals such as more efficiency, productivity, acquire knowledge, collaboration. Increased use of Information technologies in the university requires a robust technical infrastructure and adequate network architecture (Yoloye, 2015).

Computer Networking enables modern world to exchange information through an interconnection of systems with the purpose of exchanging information regardless of the locality by implementing certain set of rules which are defined within the system, different systems can connect in various ways to achieve certain objectives (Grandhi, 2014).

Globally, academics including scientists and professors use the internet extensively and this explains why educational institutions were early adopters of the internet (Orike & Okereke, 2017).

In developed countries, LAN infrastructure on majority of the campuses has been upgraded from 100 Mbps to a fully redundant and scalable 10Gigabit per second backbone (Kezar, 2014).

The strengths of the internet for academic work include currency of online information sources, accessibility to multimedia resources and information that is not limited by distance or time constraints.

The increased use of the internet in worldwide academic institutions means that educational researchers recognize the significance and understand how and why students use it.

New models are being used to leverage existing infrastructure, add enhanced services and support the total infrastructure. Many new services have emerged to realize ubiquitous computing environments, owing to the increasing supply of mobile devices and more widespread Internet and wireless network facilities (Kezar, 2014).

The African continent has seen the growth of Internet connectivity in recent years, the number of Internet users has also seen an upward trend since then. ITU data indicates that

number of the Internet users has doubled since 2009 to 25 % in early 2016, there is a significant diversity in Africa, with only a few well- connected countries like Mauritius 16.70%, Morocco 57.30%, Nigeria 47.90%, Seychelles 57.60%, South Africa 51.60%, and Tunisia 50.50% attaining a connectivity level of around half of the population. These countries also lead in utilizing the Internet for education (ITU, 2016).

According to (Penard, 2015), the lack of appropriate network infrastructure that allows for easy access to information within institutions is a great limitation to the educational system in sub-Saharan countries like Kenya 66% of internet usage.

According to (ITU, 2016) the internet usage is at 4.40% of internet users in Burundi, with an effective availability of network infrastructure, users (students and lecturers) can get the information content whenever they want, in any media, over any facilities, anywhere implying that research and education networks have been established. Majority of the higher education institutions have limited access to connectivity due to their obsolete or lack of appropriate network design in place.

This is due to several barriers that affect usage of the said resources such as: slowness of the internet, network unreliability, lack of consistent technical support, poor network design which limit access to resources and old technology equipment (Adeleke, 2016).

The main factors of unreliability, slowness and network congestion in higher education is related to poor network design, misuse of bandwidth and it is based on these that this study will focus on enhancement of enterprise network performance through virtual local area network implementation.

Reliable internet connectivity has become a prerequisite for universities to provide quality education and undertake quality research works, despite these considerable investments, some universities continue to find themselves having slow and unreliable network (Akpah & Mireku, 2017).

However, nowadays the high-speed network makes people to sense that network is a much more powerful tool to enhance in any business enterprise and make the company running more efficient.

The main purpose of the network ability in the universities is to support learning, teaching, research and sharing of information (Akpah & Mireku, 2017).

In spite of the fact that the usage of internet resources in lessons preparations and learning is a necessity in improving quality of teaching in higher education institutions in Burundi, these resources the usage by lecturers and students and staff in higher education institutions in

different private and public universities first low, the enterprise network resources accessibility (Elvis, 2017).

1.2 Statement of the Problem

The world has undergone a technological revolution with the internet and web becoming an important part in lives since it provides many effective services in many fields of life (Walaa , Norah, & Badryah , 2016)

A university campus network (Wired and Wireless local area network) is an important instrument for communication and facilitating collaborative research which are key factor to build a strong knowledge culture and efficiently support academic mission (Martinez Rivera, 2015). The implementation of campus university network help universities becomes more a collaborative center, which helps achieve their goals and provide development of higher level of knowledge for the students (Rawat, 2016).

Unfortunately, even though the capacity of the bandwidth considered to be sufficient, the network can appear slow and inconsistent due to some factors like the poor network design, the number of devices on the network, local network protocols (media access control address protocol) and misuse of the bandwidth by accessing to bandwidth hungry websites and applications (Dhurgham , 2018).

Modern organizations are facing problems related to poor network design which affects services in many fields that leading the responsible categories to interested in improving network local area performance by measuring the quality of services for the network (Walaa , Norah, & Badryah , 2016).

Université Lumière de Bujumbura is facing some challenges due to inconsistent and slow network, students and staff are being affected for not doing their daily activities for accessing on books, doing their research, sharing information and other resources this brings frustration to both sides as long as the network is down nothing can be done.

Université Lumière de Bujumbura is lagging behind poor network design and a lack a virtual local area network to improve the existing network architecture.

According to ubuntuNet alliance (2017) Burundi has left the country's research and education struggling to afford high speed and affordable internet connectivity.

To help Université Lumière de Bujumbura solve problems related to poor network performance, a virtual local area network can improve the network performance by

restructuring the network infrastructure design, configuration of network devices and network interface capacity.

The research was intended to enhance enterprise network performance through virtual local area network implementation that helped to solve the issues related to inconsistent and slow network access at Université Lumière de Bujumbura.

1.3 Objectives of the Study

1.3.1 Main Objective

To enhance an enterprise network performance through virtual local area network implementation at Université Lumière de Bujumbura Kinindo, Bujumbura, Burundi.

1.3.2 Specific Objectives

The study was guided by the following objectives

i. To investigate the user satisfaction of the enterprise network performance at ULB.
ii. To identify the drawbacks of existing enterprise network performance at ULB.
iii. To measure the existing enterprise network performance at ULB
iv. To rectify the drawbacks of existing enterprise network using virtual local area network.
v. To simulate and compare the new (VLAN) and existing (NO_VLAN) enterprise network performance.

1.4 Research Questions

1.4.1 Main research question

How to enhance an enterprise network performance through virtual local area network implementation?

1.4.2 Specific research question

i. To what extent were the users satisfied with the enterprise network?
ii. What were the drawbacks of existing enterprise network performance?
iii. What were the recommended tools for measuring the existing performance of enterprise network?
iv. How were the drawbacks rectified using virtual local area network?
v. What were the recommended tools and results for simulating and comparing the new (VLAN) and existing enterprise network performance?

1.5 .Scope of the Study

1.5.1 Geographical Scope

The study was conducted in Burundi at Université Lumière de Bujumbura, Université Lumière de Bujumbura is among charted private universities in Burundi, Université Lumière de Bujumbura (main campus) is located in kinindo, Bujumbura, Burundi. The University utilizes both wired and wireless local area networks to simply the exchange of information between students and staff and within administration.

1.5.2 Time Scope

The study activities started from September 2019 up to September 2021.The researcher had approximated this to be enough time favorable for proposal writing, data collection, analyzing, virtual local area network implementation and writing the final report.

1.5.3 Content Scope

The study investigated the end-user satisfaction of the enterprise network performance and identify the drawbacks of existing enterprise network performance. After data was collected, the researcher used OPNET simulator to simulate the existing enterprise network and the new with implementation of virtual local area network for improving the network performance at Université Lumière de Bujumbura. The study was specifically concentrated to simulate and compare the existing (NO_VLAN) and new (VLAN) enterprise network performance. Therefore, analyzing network design of the infrastructure of the local area network (LAN) used at ULB and identify the issues arising from the existing of local area network (LAN) in order to implement virtual local area network for an effective and efficient network design for an improved enterprise network performance. Therefore it is the only campus which is in quarter where the research stays and know that ULB has been facing those challenges of unstable network that triggered the researcher to do research about that.

1.6 Significance of the Study

Université Lumière de Bujumbura used the findings of this research to enhance existing enterprise network or local area network performance, Since the proposed virtual local area network was implemented in OPNET simulator for comparing the performance of the existing enterprise network with NO_VLAN and the other with VLAN for accessing and supporting learning, teaching, research and sharing of information at Université Lumière de Bujumbura' network.

The researcher in the same area of networking may use the findings of this research as background to solve the problems related to networking in different sectors.

The students and staff can benefit from this study for accessing the network of good quality by helping them to perform well their daily campus activities like learning, teaching, research and sharing of information.

1.7 Definition of key terms

Enterprise network: contains of physical and virtual networks and protocols that serve the dual purpose of connecting all users and systems on a LAN to applications in the cloud and data center as well as facilitating access to network data and analytics.

Network performance: indicates to measures of service quality of a network as seen by the customer.

Virtual Local area network: is any broadcast domain that is segmented and isolated in a computer network at the data link layer.

CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

This chapter presented a review of the current literature on the topic by examining present and past research published in research papers, magazines, books, journals and conferences on the quality of service. The previous chapter outlined some of the issues and research questions relating to network performance. This chapter covers the following topics: concept review, empirical review, Overview of enterprise network (LAN), Drawback's enterprise network (LAN), Overview on virtual local area networks, Benefits of Virtual local area network, Benefits of network segmentation and VLAN Architecture.

2.1 Conceptual review

The computer network is composed of a computer use and communication facilities, that is, the use of various means of communication, the geographical dispersion of the computer together to achieve mutual communication and sharing software, hardware and data resources and other systems (Yunzhou, Xianglin, & Jianbin, 2018). The computer network according to its computer distribution range is usually divided into local area network and wide area network (Yunzhou, Xianglin, & Jianbin, 2018). Enterprise network or Local area network coverage of the geographical range is small, usually in the number of meters to tens of kilometers (Yunzhou, Xianglin, & Jianbin, 2018).

VLAN is a set of users in different isolated logical LANs or broadcasting domains, they are communicated as a same LAN i.e., same broadcasting domain (Dhurgham , 2018). A local area network (LAN) is a group of computers that are connected together in a small geographic area to communicate with one another through wired or wireless link and share resources such as printers and network storage (Hameed, A; Mian, A N;, 2015).

A local Area Network can be defined as a group of users or workstations that are located in the same physical area and has the same broadcasting domain (Dhurgham , 2018).

the local area network (LAN) is a group of computers and associated devices that share a common communication line or wireless link and typically share the resources of a single processor or server within a limited geographic area (Abid & Yousif, 2016). interconnection of computers and network devices within a geographical area and providing shared access to printers, file servers and other network devices (Grandhi, 2014). A virtual local area network (VLAN) is defined as a local area network configured by software, not by physical wiring (Gyan & Sadhana, 2018).

According to Nwaso (2018) a VLAN is a logical grouping of network users and resources connected to administratively defined ports on a switch.

A Local Area Network (LAN) is usually defined as a broadcast domain which means that all connected devices are in the same physical LAN can communicate without the need for a router (Sarah , 2016).

Virtual LANs (VLANs) which regularly defined as a set of devices on different physical LAN segments which can communicate as if they have a common LAN segment. Switches using VLANs to divide the network into separate broadcast domains without having the latency problems (Khaffaf , 2018).

2.2 Empirical review

According to Dhurgham (2018) tried to alleviate the end-to-end delay by using the VLAN technology to enhance the network performance, measuring key performance indicators such as traffic sent, traffic received, average delay and throughput by employing OPNET 17.5 Student Version, he found that there is more existing traffic without virtual local area network technology, hence, virtual area networks prohibit access to the network resources of other departments.

The objective of this article was to look at the benefits of network virtualization through the implementation of Virtual Local Area Network using cisco Packet tracer to simulate the network architecture, the network was enhanced when the network broadcast domain is segmented into separate Layer 2 broadcast domains because, if a broadcast is not well contained in a network, it may lead to collision (Isiaka & Akeem , 2015).

The aim was to enhance network performance without incorporating additional hardware cost, OPNET Modeler 14.5 simulator has been used to first implement the entire network infrastructure, observed that the proposed design significantly performs better using VLANs (Khurram , Munam , & Carsten , 2016).

The research was interested in improving quality of service using VLAN technology by overcome delay problem using OPNET simulator the simulated results show how to select a good way in designing network to reduce the value delay for improving the quality of service (Walaa , Norah, & Badryah , 2016).

In 2016 Sarah divided one physical network into multiple broadcast domains where different scenarios were designed and simulated, step by step procedure using the workspace of

OPNET is given, the results obtained show a large reduction in traffic carried by the switch with more secure and efficient bandwidth utilization.

2.3 Overview of enterprise network (LAN)

A local area network (LAN) or enterprise network is a group of interconnected computers which inter-operate and allow users to share resources, obviously no more than 1,000 feet of cable. A Local Area Network (LAN) is generally the network of computers located in the same area. Today, Local Area Networks are defined as a single broadcast domain (Jayan & Kshama, 2017).

This means that if a user broadcasts information on enterprise network or Local area network, every user will receive the broadcast. on the local area broadcasts are prohibited from leaving a Local area network by using a router. The drawback of this technique is for the incoming data routers usually take more time to process compared a switch or to a bridge. More significantly, formation of broadcast domains depends on the physical connection of the devices in the network. VLANs were developed as another solution for using routers to contain broadcast traffic**.**

The increase in the number of devices on LAN become paramount as we populate the network with more switches and workstations, since most workstations tend to be loaded with existing operating system, it results in unavoidable broadcasts being sent occasionally on the network, Unfortunately, each host on such network cannot escape from the effects generated by such uncontrollable broadcast which decreases network performance (Nweso, 2015). A local area network (LAN) is a group of computers that are connected together in a small geographic area to communicate with one another through wired or wireless link and share resources such as printers and network storage (Hameed, 2015).

2.3.1 Virtual LAN and NO_LAN with network protocols And Design

Understanding virtual local area networks, firstly it is essential to have an understanding of local area networks. A Local LAN can normally be defined as a broadcast domain. Hubs, bridges or switches in the same physical segment (s) connect all end node devices. End nodes can communicate with each other without the need for a router. Communications with devices on other LAN segments requires the use of a router.

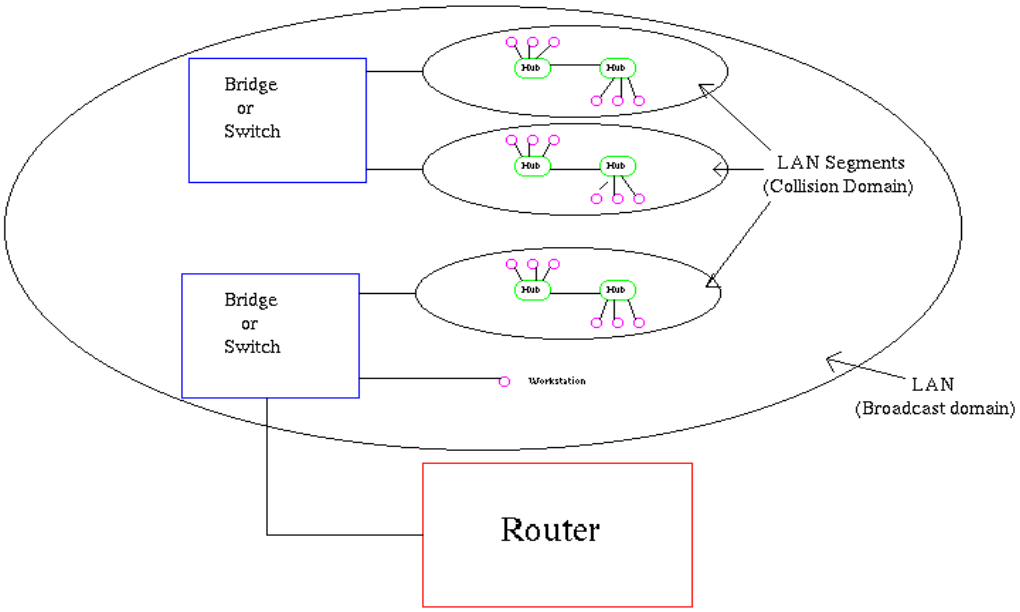

Figure 2. 1 Physical view of a LAN
adopted from Sarah , 2016.

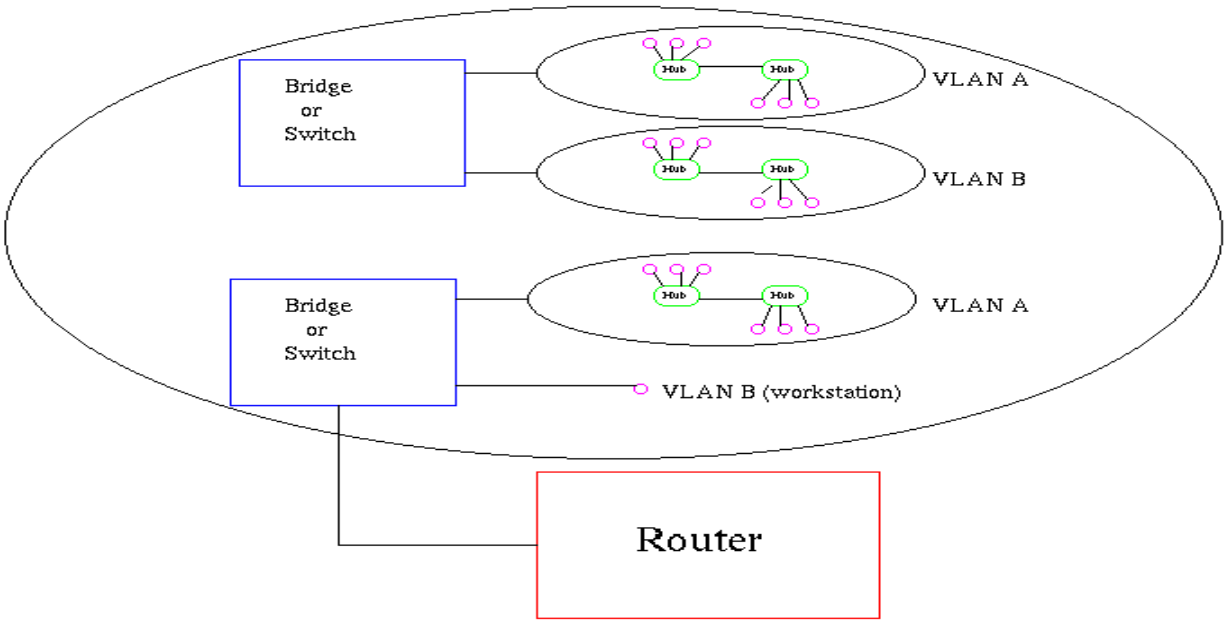

Figure 2. 2 Logical View
adopted from Sarah , 2016.

Virtual local area networks can be viewed as a group of devices which are on different physical local area network segments which can communicate with each other as if they were all on the same physical LAN segment. Switches using virtual local area networks create the

same division of the network into isolated broadcast domains but don't have the latency problems of a router. Switches are equally an extra cost-effective solution.

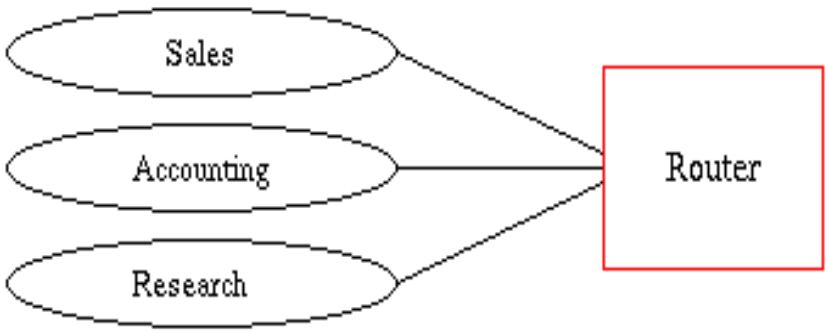

Figure 2. 3 Physical and logical view of a VLAN
adopted from Sarah , 2016.

The most commonly protocol used nowadays to configure Virtual LANs is IEEE 802.1Q. The committee of IEEE defined this technique of multiplexing Virtual LANs in an effort to provide multivendor virtual Local area network support. Previous introduction of the 802.1Q standard, several proprietary protocols existed, such as Cisco's ISL (Inter-Switch Link) and 3Com's VLT (VLAN Trunk). Cisco also implemented VLANs over FDDI by carrying Virtual LAN information in an IEEE 802.10 frame header, opposing to the purpose of the IEEE 802.10 standard.

Both ISL and IEEE 802.1Q tagging is done "explicit tagging" - the frame itself is tagged with Virtual LAN information. ISL uses an external tagging process that does not modify the existing Ethernet frame, while 802.1Q uses a frame-internal field for tagging, and thus does change the Ethernet frame. This internal tagging is what allows IEEE 802.1Q to work on both access and trunk links: frames are standard Ethernet, and so can be handled by product hardware.

Under IEEE 802.1Q, the maximum number of Virtual LANs on a given Ethernet network is 4,094. This doesn't impose the same limit on the number of IP subnets in such a network, meanwhile a single virtual local area network can contain multiple IP subnets. The VLAN limit is expanded to 16 million with Shortest Path Bridging (Rik, 2014).

Primary network designers frequently configured virtual LANs with the purpose of reducing the size of the collision domain in a large single Ethernet segment and consequently improving performance. When Ethernet switches made this a non-issue in consideration

turned to reducing the size of the broadcast domain at the MAC address layer. A virtual LAN can also serve to restrict access to network resources without regard to physical topology of the network, although the strength of this method remains debatable as VLAN hopping (Rik, 2014) is a means of bypassing such security measures. Virtual local area network bouncing can be mitigated with proper switch port configuration.

2.3.2 Drawbacks enterprise network (LAN)

Local area networks are designed to reduce the number of switches and routers on connecting the devices to a single switch computer network instead of separate switches, or by using network hubs rather than switches to connect devices to each other (Melnick, 2019).

The topology of a local area network is not separated or segmented into different broadcast areas by using switches and routers (houston, 2017). Unlike VLAN design, the network is logically separated into different broadcast domains. Normally, on local area network all devices belong to the same broadcast area. It is believed that if these problems are properly addressed, network performance could be significantly improved (Varadarajan, 2016).

Wrong choice of routing protocol: RIP is a distance vector protocol which uses only hop count for the best path selection, RIP is configured as routing protocol; however, RIP suffers from many disadvantages such as slow convergence and lost periodic updates.

No access policies: if there are no user access policies enforced which is allowing user to download or upload personal media files during the peak hours, thus causing lack of bandwidth to legitimate user.

Manual Load Balancing: the description of NOC the backup link is only used when the primary internet link fails. so, a manual switching between the ISP links is performed.

No firewall configured: A CISCO firewall is there to protect the network from malicious activities but the firewall is not configured or installed to protect the network from incoming internet traffic, the network performance can be affected.

Traffic Bottleneck: the major problem which causes local and internet network traffic bottleneck i.e., when the main Cisco 3500 series switch is deployed in NOC is limited to twelve 10/100BaseT Ethernet ports using a fast Ethernet connection (100Mbps). Having 100Mbps network interface at this point of network which redirects internal and external traffic causes traffic bottleneck.

No redundancy: It is possible for the switch to fail Subsequently when there is usually one switch, or a few devices. the network will become inaccessible and computers may lose connectivity because there is no alternative path.

Scalability and speed: When Connecting all the devices to one central switch, either through hubs or directly, increases the possibility for collisions (due to hubs) and also reduce speed at which the data can be transmitted, additional time for the central switch to process the data. It also scales severely and increases the high chance of the network failure.

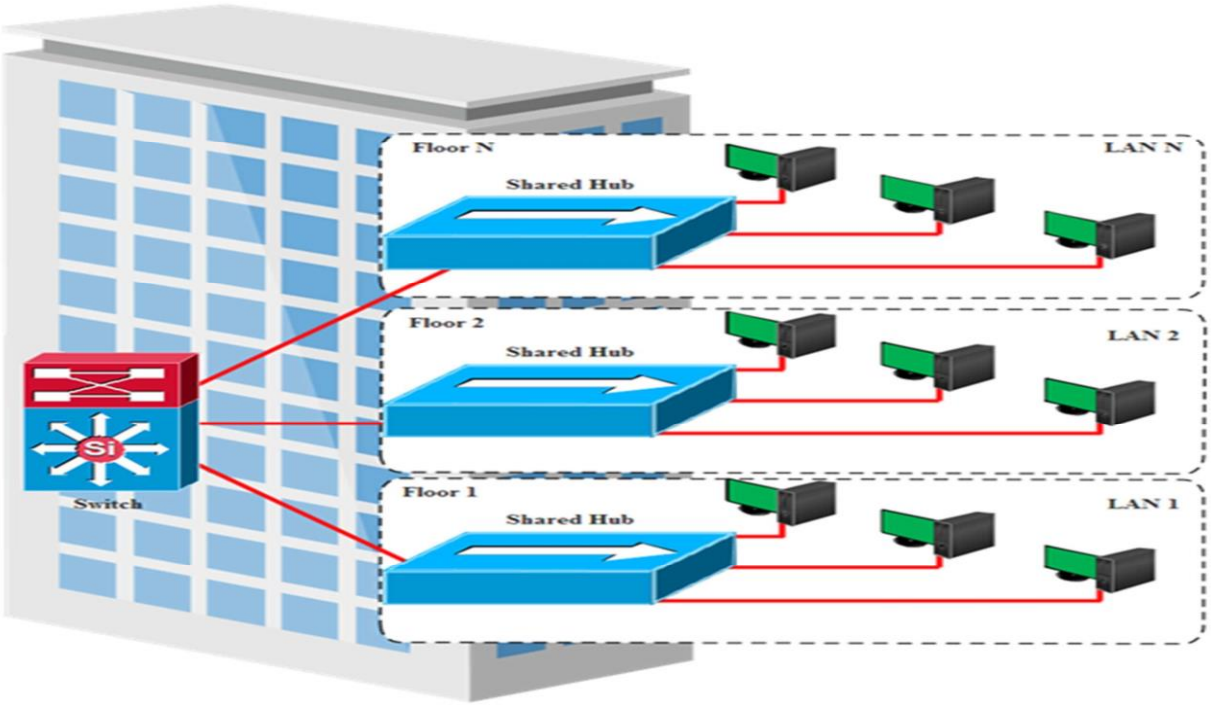

Figure 2. 4 Traditional LAN Segmentation
Adopted by Isiaka & Akeem , 2015.

2.4 Overview on virtual local area networks

A virtual LAN is the abstracts design of the LAN; A VLAN might comprise a subset of the ports on a single switch or subsets of ports on multiple switches, by default, systems on one VLAN don't see the traffic associated with systems on other VLANs on the same network (Jayan & Kshama, 2017).

Therefore, for improving network performance and scalability VLANs provide a broadcast control to eliminate unnecessary broadcast traffic. Security allows administrators to implement access lists to control traffic between virtual local area networks by logically separating users and departments.

The VLANs allow a user or device to exit anywhere by removing the physical boundaries of the network. Often user network can be separated from the server network using virtual local area networks.

Virtual local area networks technologies in Université lumière de Bujumbura (main campus) Network. Going by the normal flat local area network (LAN) infrastructure where every user belongs to one broadcast domain diverse series of network insecurities exist.

In the case of an enterprise network (LAN) having critical application servers, organizational databases, file servers and other confidential information, this mean that every user on the network would have equal access privileges to these resources.

Segmentation of the existing network into different broadcast domains using VLAN to successfully prevent such situations from operational network by restricting access at all level of network. In contrast to where every hosts are connected without segmentation in usually flat local area network architecture; a large broadcast domain into different sizes of broadcast domains is broken by creating VLANs. VLAN architecture is a logical grouping of network users and resources connected to organizationally defined ports on a switch when deploying in Université Lumière de Bujumbura Network would be of enormous benefit as outlined in the work (Burke & Terry Slattery , 2019).

In this work thoroughly show the benefits of VLAN over enterprise network or local area network in managing and maintaining of ULB Networks.

Exactly what a VLAN is and how VLAN memberships are used in a switched network, Membership in a VLAN can be based on port members, MAC addresses, IP addresses, IP multicast addresses and/or a combination of these features, VLANs are cost and time effective, can reduce network traffic, and provide an extra measure of security (Gyan & Sadhana, 2013).

In this research the local area network ULB was studied to better understand and illustrate how VLANs was used in practice to improve the performance. In this study of analyzing the local area network will indicates how VLANs will be used for many objectives that they are not originally intended for the use of VLANs complicates network configuration management (Gyan & Sadhana, 2013).

2.4 Virtual local area network usage in campus networks (LANs)

Any enterprise network administrators use virtual local area networks to achieve key policy objectives, limiting the scope of, simplifying access control policies, decentralized network management, broadcast traffic, supporting and enabling unified host mobility for wireless users. network primarily run IPv4, with relatively limited experimental deployment of IPv6 (Murugiah & Karen , 2012).

2.4 .1 Scoping broadcast traffic.

Virtual local area networks enable administrators to limit the scope of network-wide flooding and broadcast traffic, to reduce network overhead and enhance both privacy and security.

2.4.2 Limiting the Flooding Overhead/Broadcast

End hosts broadcast dynamic host configuration protocol (DHCP) traffic when joining the LAN, and routinely broadcast address resolution protocol (ARP) requests to learn the medium access control (MAC) addresses of other hosts in the same IP subnet (Jayan & Kshama, 2017).

It not only consummation of network bandwidth, but also bandwidth and energy resources on the end devices Switches also flood packets to a destination MAC address without learning how to reach. This consumes bandwidth resources, particularly if the switches forwarding tables are not big enough to store an entry for each MAC address on the local area network. Administrators often split large networks into multiple virtual local area networks to limit the scope of flooding traffic and broadcast messages. broadcast domains might be small enough to limit the overhead on the switches and the end hosts (Jayan & Kshama, 2017). .

2.4.3 Security and Privacy

In adding, a malicious host can purposely overload switch forwarding tables by spoofing many source MAC addresses forcing switches to flood legitimate traffic that can simply be monitored by the attacking host. ARP is similarly vulnerable to man-in-the-middle attacks, where a malicious host sends unsolicited ARP responses to impersonate another host on the local area network, thereby intercepting all traffic sent to the target. Network administrators can decrease these risks by constraining which users can belong to the same virtual local area network (CISA, 2019).

2.5 Benefits of Virtual local area network

In networking, a local area network has a single broadcast domain and the traffic from a workstation reaches other workstations on the Local Area Network through the broadcast, this is not desirable as certain classified information can be received by unauthorized parties Also, if the broadcast is not well contained, it can lead to collision in the network (Syed, Joshi, Vikram , & Kuriakose, 2014).

Therefore, network administrators normally protect the broadcasts from leaving a enterprise network with the aid of routers.

However, routers are usually taking more time to process the incoming data compared to switches and more expensive. VLAN developed as an alternative solution to using routers to contain broadcast traffic within a local area network, However, for broadcast filtering, employed routers in the virtual local area network topologies and also address summarization for traffic flow management (Syed, Joshi, Vikram , & Kuriakose, 2014).

A virtual local area network is a switched network that is logically segmented based on features such as service requirement, workgroup and protocol or application requirement rather than on a physical or geographical proximity (Isiaka & Akeem , 2015). With the implementation of VLAN, geographically dispersed workstations, servers and other peripheral devices used by a particular workgroup can be put on the same VLAN and communicate as if they are physically on the same location in the network (Alimi, Mufutau, & Ebinowen, 2015).This enables the network administrators to manage the network without the need for running new cables or making major changes in the network infrastructure (Isiaka et al , 2015).Therefore, virtual local area network is addressing that security, flexibility, scalability and network management issues which are associated with the traditional.

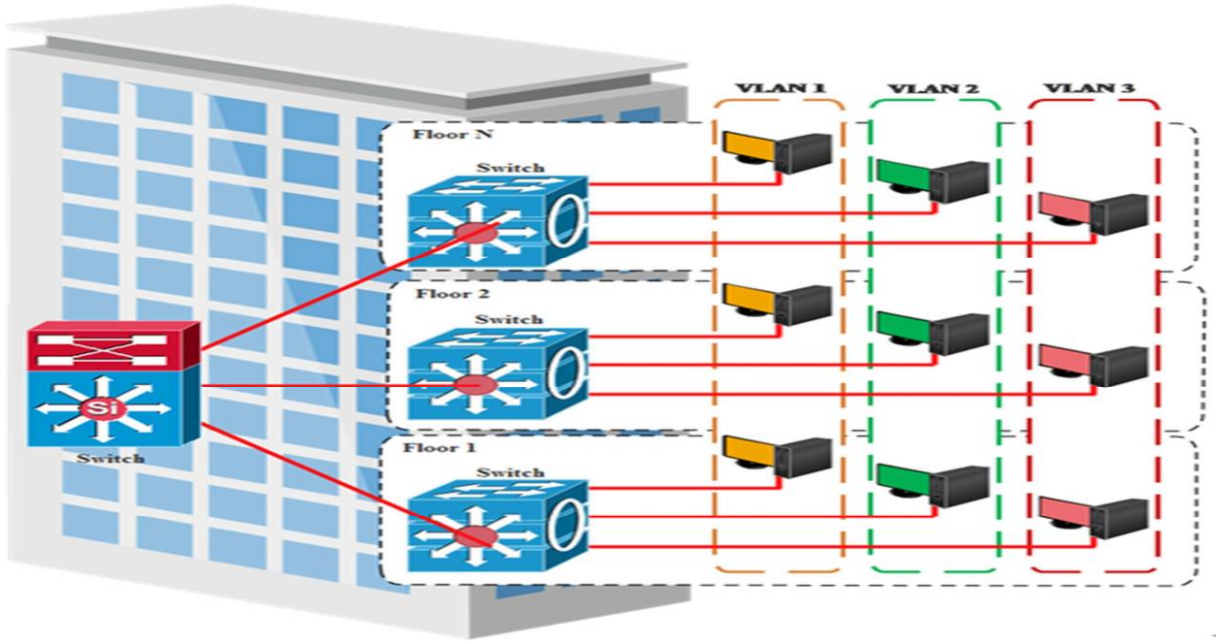

Figure 2. 5 VLAN based LAN segmentation
Adopted by Isiaka & Akeem , 2015.

Security: Virtual local area networks (VLANs) provide improved network security. In a virtual local network environment, in multiple broadcast domains, the network administrators

have control over each port and user. A malicious attacker can no longer just plug their workstation into any switch port and sniff the network.

Creating Workgroups: A group of users that need a remarkably high level of security can be put into its own Virtual local area network so that users outside of that virtual local area network can't communicate with it. This suggests that in an enterprise each department can be made independent from another departments.

Scalability: Network moves, changes and adds are achieved easily by just configuring a port into the appropriate Virtual local area network and assigning hosts to the same Virtual local area network traffic using a packet sniffer. Network administrator controls each port and all resources VLAN is allowed to use. Virtual local area networks help to restrict sensitive traffic originating from an organization department within itself.

Cost effective: eliminating the need for additional expensive network equipment like switch, routers, can be cost savings to an organization. Virtual local area networks can also allow the network to work more efficiently by commanding a better use of bandwidth and resources.

Easy Troubleshooting: VLANs group the network users and resources into different VLANs, can emanate many problems in the network and can easily be identified and fixed by tracing group such hosts where belong to.

Integrity: Users are being logical grouped according to function, virtual local area networks can be considered independent from their geographic or physical locations. Thus, University data can be handled without comprise mostly to the universities that have branches.

Broadcast Control: The management of broadcast network can be controlled by creating many virtual local area networks which always increases the number of broadcast domains while decreasing their size.

2.6 Benefits of network segmentation

Running traditional flat networks is now an ageing model and it is an outdated assumption that everything on the inside of an organization's network should be trusted (Julian, 2018). By segmenting a network and applying appropriate controls, we can break a network into a multi-layer structure that hinders threat agents or actions from reaching hardened systems and restricts their movement across the network (Fort, 2018).

While it should be understood it isn't possible to create the perfect IT network infrastructure defense, reducing the attack surface and elimination of unwanted access to network segments significantly reduces the risk of system breach. Using the defense-in-depth security practice of network segmentation, an organization's network address space is subdivided into smaller

subnets (Olzak, 2018). The network can be physically segmented with routers, firewalls, or more commonly, logically separated by virtual LANs (VLANs) on network switches. These VLAN zones are interconnected with trunk links or Switched Virtual Interfaces between them. There are numerous advantages to implementing this segmented network architecture (Julian, 2018).

- This type of segmentation directly decreases the number of systems on the same network segment and reduces the broadcast domain, thus reducing device network processing and malicious reconnaissance. By limiting routed traffic to segments, the overall bandwidth usage in the LAN is reduced.
- The propagation of network worms such as WannaCry and NotPetya over a shared protocol such as SMB is not limited on a flat network as it would be on a segmented network.
- Segmentation aids compliance by separating zones that contain data with similar requirements whilst ensuring that systems holding sensitive data are kept isolated.
- Network segmentation enables segregation of systems by end-user category groups with facilitation of access control policy at the ingress/egress points. This granulation of security policy can be implemented over time with ACLs at the zone gateway or Firewalls that control the flow for large segments.
- Further division of server systems, for example, protects against threat actors easily pivoting from one compromised server to another, such as performing lateral movement with mimikatz pass-the-hash attacks (namely collecting hashed credential data for use on different machines.
- Often network segmentation projects can be run with current network equipment.
- Facilitate the addition of an untrusted VLAN for NAC Policy enforcement. NAC solutions allow network operators to define policies for enforcement, such as the types of computers or roles of users allowed to access areas of the network. This is then enforced using switches, routers, and firewalls. Implementing an untrusted VLAN segment can protect the network from non-compliant and/or unknown systems.

2.7 VLAN Architecture

With the creation of virtual local area networks many problems can be forgotten. in order to create VLANs, a layer 2 switch is need that can support such protocol (Agwu & al, 2015). A.

the misconception of many new people in networking field that it's a matter of just installing additional software on the clients or switch, in order to "enable" VLANs throughout the network, it is completely incorrect. It is not true, rather have virtual local area network enabled switches like cisco catalysts switches for the cisco system.

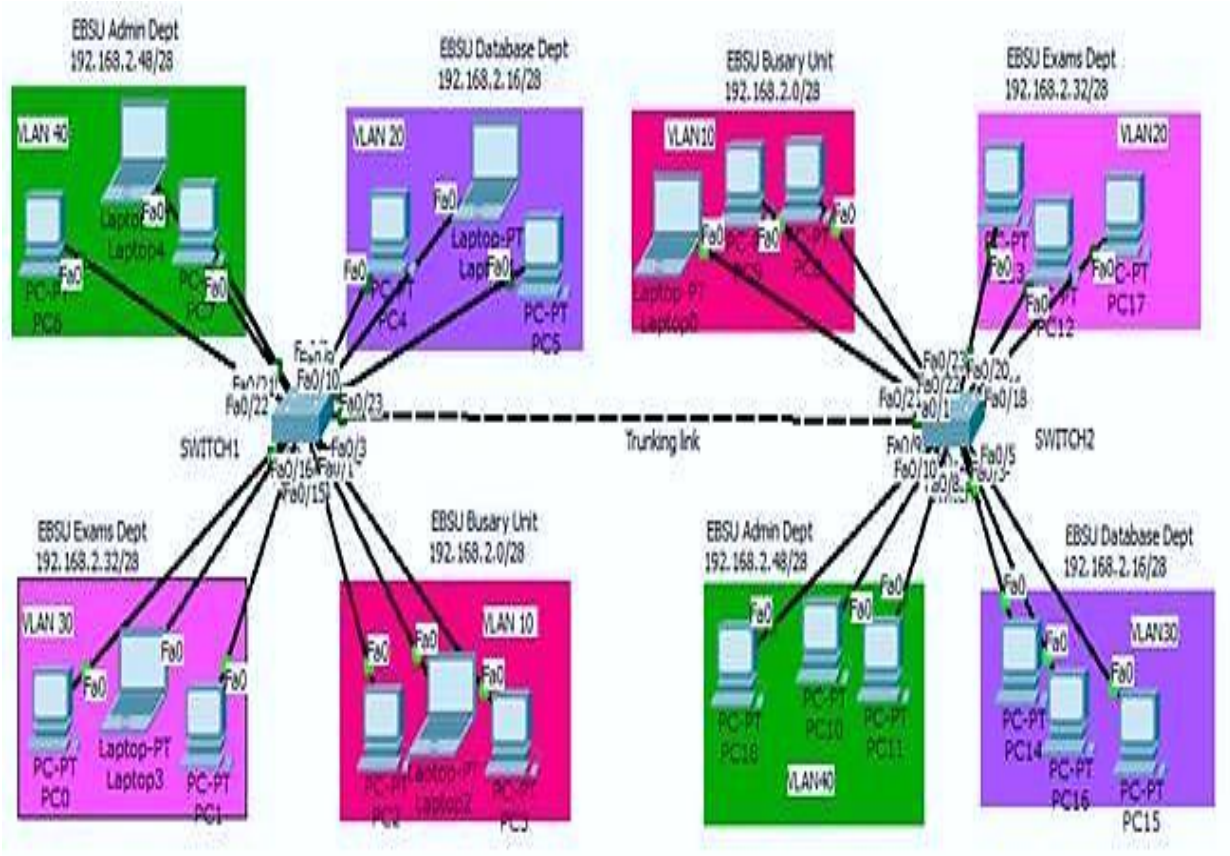

Figure 2. 6 VLAN Infrastructure

VLANs involve millions of mathematical calculations, they require special hardware which is built into the switch and your switch must therefore support VLANs at the time of purchase, otherwise you can't create VLANs on it (Nweso, 2015).

A switch is a separated network on Each VLAN created on. by default, network broadcasts, are filtered from all ports on a switch that are not members of the same virtual local area network. This is the reason why network a virtual local area networks are very important in today's large network on University Lumière de Bujumbura, they can help segmentation and poorly design firewalls can extremely compound the problem already caused by these broadcast intensive applications (Ojiugwo & al, 2015). A. Network design presents a lot of new challenges for administrator by using all this new dimension of network design.

2.8 Gap Identification

With the drawbacks that have been identified and indicated, the researcher has identified the literature gap because to the research that have been done by the researchers there is no article or any published paper that has talked about this matter.

There is also geographical gap in that virtual local area networks implementations have not been used in most universities in Burundi.

CHAPTER THREE
METHODOLOGY

3.0 Introduction

This chapter presented the methodology that was used in data collection and analysis. The study used quantitative and qualitative approach. The specific methods for data collection was reviewed in the literature. Questionnaire was used for gathering information from the end users (students) for investigating the user satisfaction of the enterprise network performance at ULB.

while structured interview guide was used on objective two to get deep understanding on identifying the drawbacks of existing enterprise network performance from the network and system administrators at ULB. Therefore, on objective three and four riverbed modeler academic edition 17.5 (OPNET) was used to simulate and measure the enterprise performance for both scenarios in objective three existing enterprise network with NO_VLAN was simulated and measured as the same on objective four new enterprise network with implementation with VLAN was simulated using OPNET and the objective five was to simulate both scenarios VLAN and NO_VLAN to compare the both enterprise network performance scenarios. A literature review was used to understand how a local area network works and as well virtual local area network to be able to know how they both perform so that the network can be enhanced. By getting deep understanding of LAN network performance issues so that virtual local area network was implemented to enhance the performance. Finally, the researcher simulated the enterprise network for both NO_VLAN and VLAN network to demonstrate how virtual local area network implementation improved the existing enterprise network performance (NO_LAN).

3.1 Research approach

The research used a descriptive research design, where quantitative and qualitative approach was used (McCombes, 2019). In qualitative approach, the researcher utilized data which was collected in form of numbers where he/she will simulate and measure the performance of the current enterprise network (LAN) and the virtual local area network which was implemented. Qualitative approach was used through interviews in order to describe the activities that are being done through enterprise network and impact of its poor performance (Patrik & Ugo , 2019).

3.1.0 Qualitative and quantitative research

Both qualitative and quantitative methods was used in this research work. A brief discussion of all these methods was described. Sometimes data is quantitative such as in the field of climate science researchers gather and compare statistics such as temperature or atmospheric conditions of carbon dioxide (Veal, 2015). At other times data is qualitative and is presented in a qualitative form such as numerical scores calculated by asking participants how they think the risk is in the scale of 1 to 5,1 being very significant and 5 being very significant (Veal, 2015).Quantitative research is performed to determine the relationship between an independent variable and a dependent variable in a population (Creswell, J. W, 2016). Quantitative research is based on the numerical representation of the independent variable for explaining and describing a relationship. Quantitative research was used to explain different phenomena in both pure and social sciences. quantitative research generates knowledge and create understanding about the social world and also to observe phenomena or occurrences affecting individuals. qualitative research is non-numerical examination and interpretation of observation of relationships (Creswell, J. W, 2016). It is the investigation of the problems and seeks to answer why rather than how many in an unstructured method. The data generally consists of open-ended responses that is gathered by researcher from a relatively small number of subjects (Creswell, J. W, 2016). Qualitative research usually deals with insufficient evidence and is considered soft social science. With strong confidence that both qualitative and quantitative research methods are equally significant difference for explaining diverse social and scientific phenomena.

3.1.1 Qualitative Research Methodology Approach

Strengths

- View of homogeneous exploration
- Raise more issues throug0h broad and open-ended inquiry.
- Understanding behaviours of values, beliefs and assumptions.

Weaknesses

- No objectively verifiable result.
- Skilful requirement for interviewers.
- Time consuming during interviewing process and intensive category process.

3.1.2 Quantitative Research Methodology Approach

Strengths

- Reliability by critical analysed.
- Short time frame for administered interview.
- Facilitated numerical data for groups and extents of agree or disagree from respondents.
- Provides accurate, quantitative, numerical data.
- Research results are independent of the researcher

Weaknesses

- No human perception and beliefs.
- Lack of resources for large scale research.
- No depth experience description.
- as the emphasis is on hypothesis testing and not hypothesis generation, the researcher might miss out on phenomena occurring.
- Body of knowledge produced might be too abstract to be applicable to local contexts or situations.

3.1.2.1 qualitative research methods

Quantitative data analysis methods were used to apprehend the dimension and structure of a data set. It is not usually feasible to provide an explanation for large information set by physical observation for patterns. Hence, suitable data analysis method, will be chosen in accordance to

The nature of data and the purpose of the study was used. There are numerous data analysis methods available (Goundar, 2012).

The study used scientific dimension and qualitative formulas to calculate and analyze several mounts of this data that will be obtained from simulation of enterprise network performance. Data was collected from the existing enterprise network helped for the implementation of virtual local area network. After implementation of virtual local area network, more data was collected and analyzed and then compared to the previous data using well known mathematical tools and formulas.

3.2 Research design

Research design is the set of methods and procedures used in collecting and analyzing measures of the variables specified in the problem research. The study used descriptive comparative research design is interested in establishing whether there are significant differences among variables of interests, which are between the existing (NO_VLAN) and new (VLAN) enterprise network performance (Sileyew, 2019).

3.3 Questionnaire

A questionnaire is a research instrument consisting of a series of questions for the purpose of gathering information from respondents. Questionnaires can be thought of as a kind of written interview (Saul , 2018). Data can be collected quickly because the researcher would not need to be present when the questionnaires were completed. This is useful for large populations when interviews would be unfeasible. Questionnaires provide a relatively efficient, cheap, and quick way of obtaining large volumes of information from a large sample of people. they can be carried out by telephone, face to face, Post or computer. the questionnaire was used for objective one to collect data to the respondents, on they feel with the enterprise network performance at ULB.

3.4 Interviews

Interviews were used for data collection by asking questions to participants to obtain data about the problem that happened to get more information that problem. Interviews may be structured, unstructured and semi-structured. They may be conducted face to face by telephone or online.

3.4.1Structured interviews

The structured interview was conducted with a set of pre-determined questions. Normally the interviewer reads out the questions in their order and records the responses in a standardized schedule (Saunders, Lewis, & Thornhill, 2015). The researcher reads out pre-coded questions and does not change them during the interview. Structured interviews are normally used to collect quantifiable data (Saunders, Lewis, & Thornhill, 2015).

3.4.2 Unstructured interviews

Unstructured interviews were those that do not involve pre-planning the order of questions. They are also known as in-depth interviews where the interviewee is given a chance to talk freely about events, behavior, and beliefs about the topic at hand (Saunders, Lewis, &

Thornhill, 2015). According to Creswell (2014) the questions posed to the interviewee in an unstructured interview aim to find out views and opinions from the participants. this type of interview will have continuation of questions.

3.4.3 Semi-structured interviews

In a semi-structured interview, the interviewer has a list of questions that serve as a guideline on the themes and questions to be covered. As such extra questions are added during the interview to explore further the themes that come up during the interview. state that some of the pre-coded questions might not even be asked during the interview and that the conversation will be recorded by an audio recorder (Saunders, Lewis, & Thornhill, 2015). Semi-structured interviews were used in this research because they enabled the researcher to get an in-depth understanding of current enterprise network problems and user experiences. The semi-structured interviews was chosen to explore views and opinions from network administrators and users.

3.6 Experiments

According to Creswell (2014) An experiment seeks to determine if a specific treatment influences an outcome. an experiment the researcher seeks to discover relationships between variables. that is, to measure whether the change in an independent variable produces the change in two or more dependent variables. In this research, the researcher will want to find out the relationship between enterprise network (local area network) and virtual local area network performance. This means that implementing virtual local area network (VLAN) is the independent variable and enterprise network (local area network) is the dependent variable. As such the experiment will suppose outline what happens to enterprise network (local area network) after implementation virtual local area network in comparison to both performances.

3.7 Literature review

The main purpose of the literature review is to get an in-depth understanding of relevant previous research and trends that have emerged in the subject area. The literature review is used to identify theories and ideas used for testing data, then this is a deductive approach in the inductive approach, the literature review is used to frame the problem (Creswell, 2014). conducting a literature review also informs the student of the influential researchers and research groups in the field.

Literature review has a numerous purpose some of which are that it:

- ✓ report on knowledge and ideas that have been established on a particular topic, including their strengths and weaknesses while they allow you to discover the agreed academic opinion on the topic while at the same time letting you find out the disagreements on the same subject.
- ✓ position your research project within the body of literature and thereby provide perspective for the reader.
- ✓ demonstrate your knowledge of the subject area.
- ✓ determine what each source contributes to the topic.
- ✓ understand the relationship between the various contributions, identify and (if possible) resolve contradictions, and determine gaps or unanswered questions.
- ✓ justify your choice of research design; for instance, your choice of qualitative over quantitative approaches, or your method of data analysis.
- ✓ clarify how your work fills a gap in the scholarly literature.

  Writing a literature review also allows you to:
- ✓ gain expertise in the ability to scan the literature on a particular topic efficiently, and
- ✓ hone your skills in identifying and analyzing unbiased and valid data on various topics or fields of study.

3.8 Target population

The target population is the group of individuals that the intervention intends to conduct research in and draw conclusions from (Louise & Nghiem, 2018). the unit of analysis of this research was the staff in the ICT, students, faculty and administration staff at université lumière the Bujumbura (campus kinindo). The population of this study were comprised 1864 students and staff, two ICT staff (system and network administrator) were collected on data using structured interview which were network and system administrators and questionnaires were on students and administration and faculty staff on sample size.

3.9 Sample size

Sample size is a count the of individual samples or observations in any statistical setting, such as a scientific experiment or a public opinion survey (Jon, 2018).

The Slovene's formula was used to determine the minimum sample size of the study of the target population. The sample size was determined by using Slovene's (1960) formula which is as follow:

$n= N/ 1+(Ne^2)$

n= sample size

N= population size

E= level of significance = $e^2= 0.05$ e = $(0.05)^2 = 0.0025$

The sample size from students and staff: it was 1864/1+(1864*0.0025) =329.

3.10 Sample technique

This is a primary concern in statistical sampling, the sample that was obtained from the population was represented the same population. This was accomplished by using purposive non random sampling method.

3.11 Data analysis

The choice of qualitative method emphasized on understanding the phenomena and it is verbal more than being numerical in data collection generally refers to qualities over quantities. data collection is based on analysis rather than a statistical form (Syed M. , 2016). It is important to remember pre-existing theory, previous empirical research or own expectations that may influence the choice of a qualitative study. In order to avoid misunderstandings with the analysis of the interview data and questionnaire data the available recordings were wisely recorded into text. The purpose of recording into text minimized interpretation errors and allowed to conclude afterward.

Additionally, the data that was collected from the interviews and questionnaires was also link in order to make overviews to the body of knowledge to construct theory. the data analysis was an iterative approach, where data collection and analysis were occurred simultaneously in order to remain open to all options. This enables for suggestions of new questions to ask in the interviews.

In data collection there were 210 students, 3 administration staff and 6 faculty staff using questionnaire. However, there were 2 respondents' network and system administrator used structured interview guide to collect data on them.

3.12 Ethical considerations

The entire research was conducted due to respect of ethical consideration in research. The research obtained the consent of respondents to participate in the study. ethics are very significant in conduct of research and the way in which research is always under examination. There is a need to make sure succeeding issues are perceived while doing the research. In general, the high degree of openness regarding the purpose and nature of the research was observed in this study (students, 2013). The researcher got introduction letter form Kampala international university, the letter to request to cooperate and avail the researcher with the pertinent information needed. For any information shared with the research was used for academic purposes only and shall be kept with utmost confidentiality.

3.12.1 Informed consent

Informed consent is the major ethical issue in conducting research. According to Armiger (1997) it means that a person knowingly, voluntarily and intelligently, and in a clear and manifest way, gives his consent. Participants will contribute willingly without being forced by the researcher, but agreement was before they can participate in the research. The process was needed for the research to be successful. This research was not threatening the security of the participants in any way whatsoever.

3.12.2 Deception

Participants were participated knowingly and willingly; agreement was first happened and everything was explained properly to in detail before the participants did anything in the research.

3.12.3 Anonymity and Confidentiality

The researcher must guarantee the confidentiality and anonymity of the data that was provided by the participants during the research time. the data was used only for the purpose of this particular research only. Protection of the respondents must be there during and after the research study.

3.13 Riverbed Modeler Academic Edition 17.5 (OPNET)

OPNET (Optimized Network Engineering Tool) Modeler is a powerful tool which evaluates the network efficiently and accurately and predicts the network behavior before implementation in real environment. OPNET Modeler was selected because most of the wired and wireless network components are available and very important tool for network designing and simulation OPNET modeler is a very powerful for the network modeling and simulation and it is there to optimize efficiency cost, performance, viability and scalability characteristics of the network.

Network simulation is designed for characterizing, creating and validating the communication solutions, computer networks and distributed or parallel systems, it enables predicting network behavior and network performance, one can create, run and analyze any desired communication scenario (Northforge Innovations, 2015).

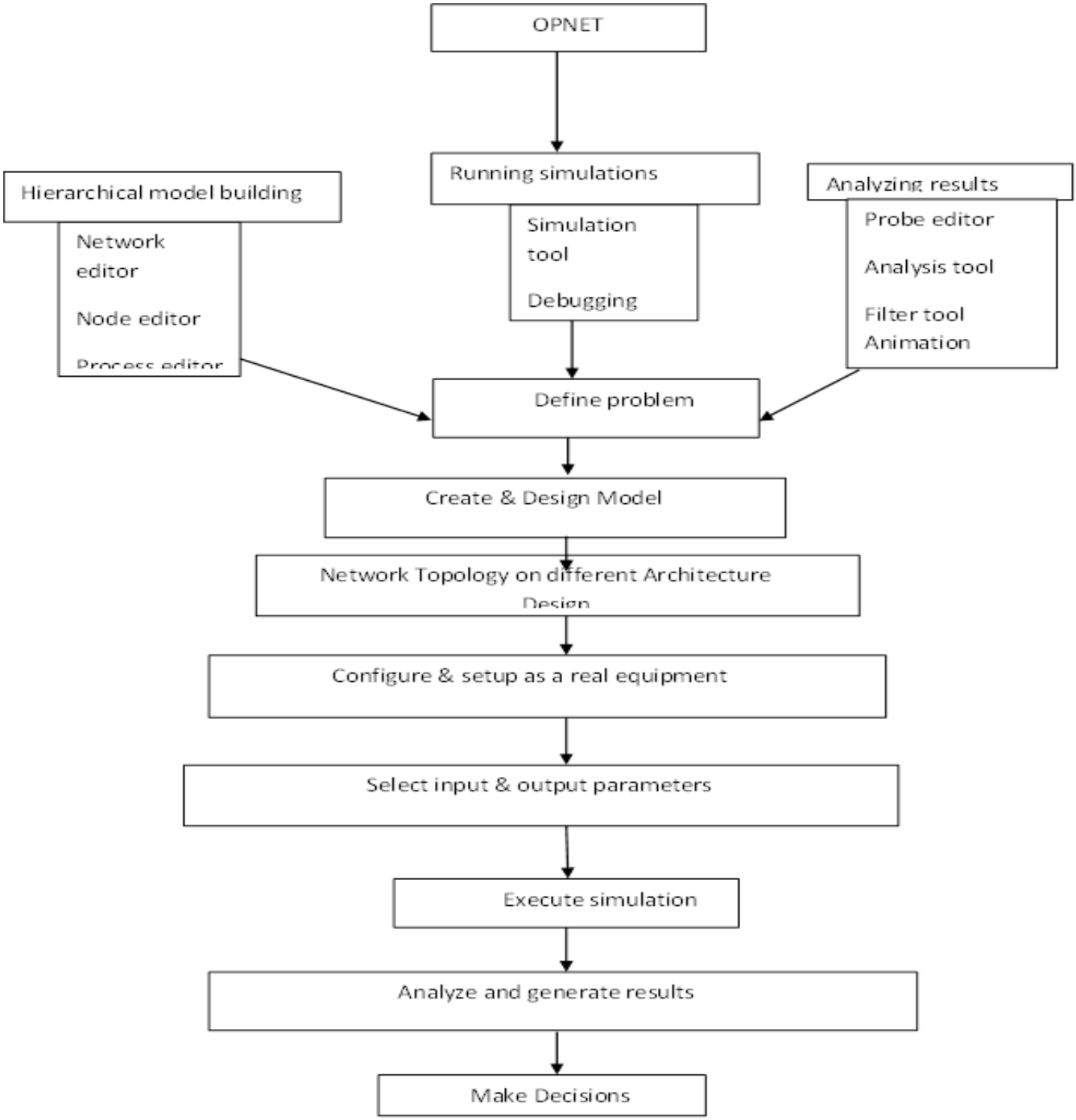

Figure 3. 1 The OPNET Architecture

Adopted by Atayero, Alatishe, & Iruemi, 2012

Step1: create a project

Step2: create a baseline scenario

Step3: import or create network topology

Step4: import or create traffic

Step5: choose statistics to be collected

Step6: run the simulation

Step7: view the results

Step8: duplicate the scenario

Step9: make change

Step10: re- run the simulation

Step11: compare the obtained results

3.10.2 The Simulation methodology

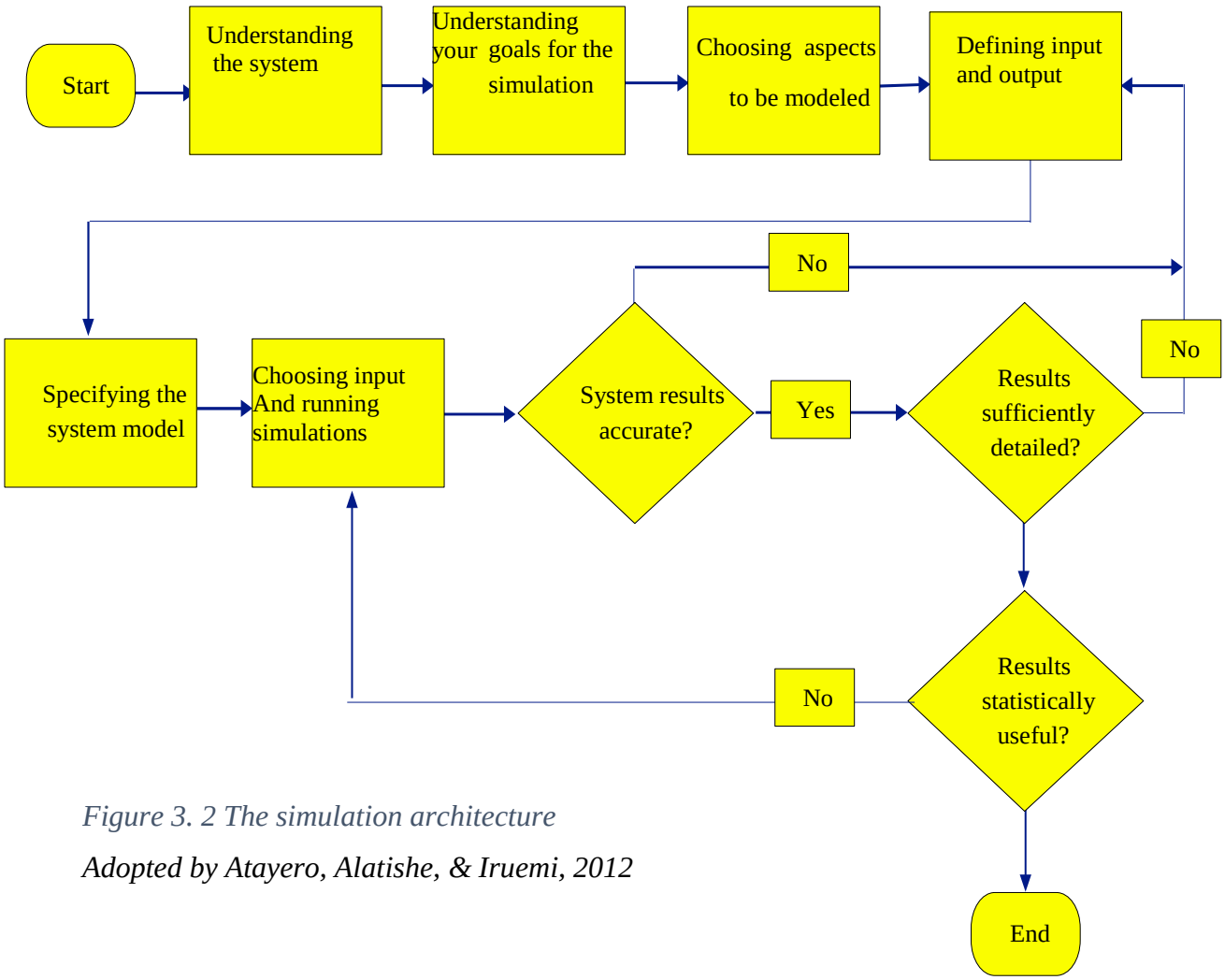

Figure 3. 2 The simulation architecture

Adopted by Atayero, Alatishe, & Iruemi, 2012

3.13.3 The three-tiered OPNET hierarchy

three domains: network, node and process:

- Node model specifies object in network domain
- Process model specifies object in node domain
- Process model specifies object in network domain

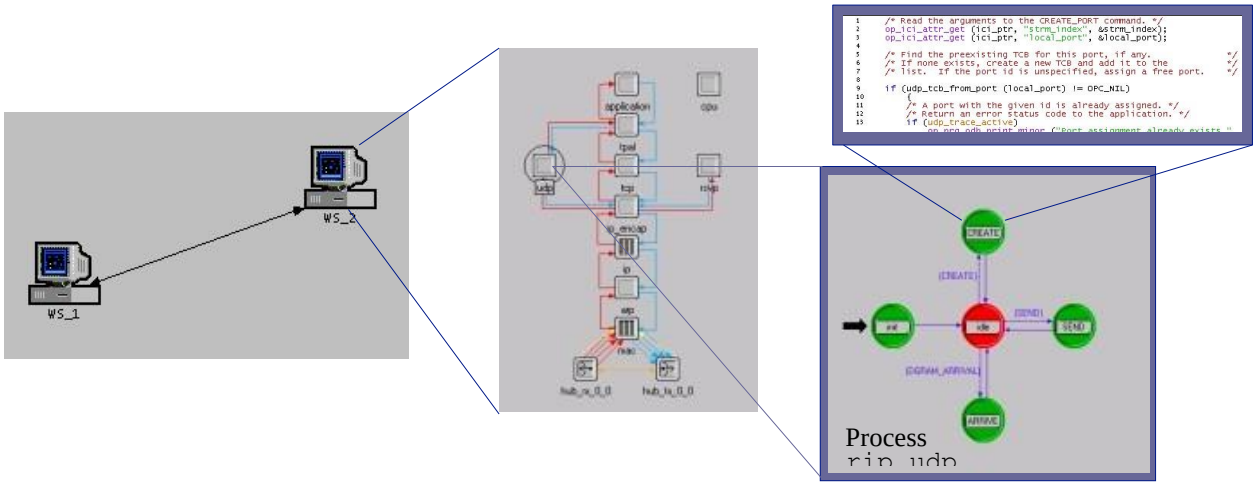

Figure 3. 3 The three-tiered OPNET hierarchy

Adopted by Atayero, Alatishe, & Iruemi, 2012

3.14 Sampling procedures

Sampling is the selection of a subset of individuals from within a statistical population to estimate characteristics of the whole population. Statisticians attempt for the samples to represent the population in question. The study used simple random sampling techniques is used when the researcher can access all respondent in groups like rotary where each respondent has got an equal chance of being selected, the research can conduct as a simple rotary (Gravetter & Forzano, 2011).

CHAPTER FOUR
DATA PRESENTATION, ANALYSIS AND INTERPRETATION OF THE FINDINGS

4.0 Introduction

This chapter presents the response rate, demographic characteristics of the respondents, and the objectives results. The data accumulated from the field (Questionnaire and Structured Interview Guide) was captured and analyzed using SPSS software, the objective one was to investigate the end user satisfaction of enterprise network at ULB, a descriptive analysis was conducted and the results were interpreted. In objective two the existing enterprise network was simulated using Reverbed modeler academic edition (OPNET) by measuring key performance indicators simulation.

The interview guide was used to identify the drawbacks of the existing enterprise network at ULB on objective three. Objective three was to rectify the drawbacks of existing enterprise network, virtual LAN was used to alleviate the end-to-end delay by using VLAN technology to enhance the network performance. In objective five, two different scenarios were presented to observe the performance of enterprise network (LAN) and VLAN networks. The simulation results illustrated that there was more existing traffic without VLAN technology. therefore, Virtual LANs prohibit the access of the network resources of other departments.

4.1 Response rate

The study was comprised of 329 respondents with structured interview and questionnaires. Out of 324 (100%) questionnaires distributed to students and staff, only 219 (68%) responded sufficient enough for meaningful data analysis.

The interviews were only for ICT technical staff; the rest of the respondents (students and other staff) were given questionnaires to offer their opinion on end user satisfaction 5 respondents consisted of ICT personals were purposively selected because they were knowledgeable in ICT technical issues from a network perspective, of these, only 2 responded; system and network administrators were availed by the ICT directorate for interviews.

4.2 Demographic Characteristics of Respondents

The demographic data of the respondents were deemed vital for internalizing study information. These were examined and presented in this section

Table 4. 1 Gender for the respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	98	44.7	44.7	44.7
	Female	121	55.3	55.3	100.0
	Total	219	100.0	100.0	

Source: Primary data, 2020

Table 4.1 showed that out of 219 responded questions there were 121 females participated in the respondents 98 Male. It implies that the majority of the respondents were female with 55.3% and male the minority with 44.7%, at ULB majority of students are females' reason being that among the students that being corrected on data, majority of respondents were females.

Table 4. 2 What is the end user role?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Student	210	95.9	95.9	95.9
	faculty staff	6	2.7	2.7	98.6
	administration staff	3	1.4	1.4	100.0
	Total	219	100.0	100.0	

Source: Primary Data, 2020

According to the Table 4.2 most of the respondents were student (95.9%), followed by Faculty staff (2.7%) and lastly administration staff (1.4%).

Table 4. 3 How do you feel with the university network speed?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-6 months	38	17.4	17.4	17.4
	6-12 months	11	5.0	5.0	22.4
	1-3 years	156	71.2	71.2	93.6
	over 3 years	14	6.4	6.4	100.0
	Total	219	100.0	100.0	

Source: Primary Data, 2020

According to the Table 4.3 the majority of respondents had spent more than 1 year to 3 years (71.2%) the respondents who had spent more than 1 month to 6 months were (17.4%) followed by ones who had spent over 3 years (6.4%) and the last were the ones who had been there from 6 months to 12 months (5.0%).

4.3 Descriptive Statistics of the Respondents Responses

The study used cross-tabulation to identify the end user satisfaction of campus network at ULB Through the first objective, a Likert Scale was used for statement regarding the satisfaction, availability and usage as shown in the tables below.

Table 4. 4 How do you feel with the university network speed?

		very unsatisfied	unsatisfied	neutral	Satisfied	very satisfied	Total
WHAT IS THE END USER ROLE?	Student	65	41	48	50	6	210
	faculty staff	1	2	0	3	0	6
	administration staff	0	1	0	1	1	3
Total		66	44	48	54	7	219

Source: Primary Data, 2020

Table 4.2.1 showed that the majority of respondents were very unsatisfied with the campus network (65) students, (1) faculty staff and there is no administrative staff which make a total of 66 respondents who were very unsatisfied with the university network performance, therefore there are (41) students who were unsatisfied with (2) faculty staff and (1) administrative staff.

In the case of the network satisfaction the majority of the respondents (110) out of 219 were unhappy with the ULB network performance. (48) students did not say anything about the network, thus, 50 students and 3 faculty staff with (1) administrative staff were satisfied with the network. (6) students were very satisfied and (1) with campus network, which means that the minority end users at ULB were happy with the network by only 61 out of 219 respondents were happy with this network at ULB.

This implies that students and staff cannot fully access their resources provided by the university network as they want, due to inconsistent and poor network. This could be caused by poor network structure of the existing enterprise network of the university which causes more traffic on the LAN which is a single broadcast domain network.

Table 4. 5 Are you contented with the availability of the campus network?

		never	rarely	sometimes	Often	Always	Total
WHAT IS THE END USER ROLE?	Student	83	49	42	24	12	210
	faculty staff	1	1	4	0	0	6
	administration staff	1	0	1	0	1	3
Total		85	50	47	24	13	219

Source: Primary Data, 2020

Table 4.5 presented majority of (83) students with one faculty and administration staff who said that they never got contented with the availability of the network at ULB (49) students and one faculty staff rarely got contented with availability. (42) students with (4) faculty staff and one administration staff said that they sometimes got contented with the availability. (24) students were often contented with the availability and (12) students with only one administration staff were always contented with the availability of the network at ULB. Due to inconsistent network at Université Lumière de Bujumbura end users cannot effectively do

their daily activities on the campus LAN. This might be probably the many end users who had accessed the network which is a single broadcast domain at this case they occur many collision domains because of much traffic on the network and the network becomes unstable.

Table 4. 6 What do you likely do with the campus network?

		download	upload	both	chat	Search	all	Total
WHAT IS THE END USER ROLE?	Student	55	28	9	12	70	36	210
	faculty staff	0	0	0	0	1	5	6
	administration staff	0	0	0	0	2	1	3
Total		55	28	9	12	73	42	219

Source: Primary Data, 2020

Table 4.6 showed that the majority of respondents (73) were using the university network doing search to access the resources on the network, (55) respondents used the network to download, while (42) respondents were doing all they want with the campus network. Among 219 respondents (28) were uploading while 12 were chatting, and the minority were both (downloading and uploading). This implies that depending of what the respondent is doing might affect the network speed for others who are accessing to the same network, because they are all accessing to the single domain network where some slows another depending what they are doing on the network which means network performance might be affected. This could be Due to that there are no user access policies enforced which is allowing user to download or upload personal media files during the peak hours, this could cause lack of bandwidth to legitime user

Table 4. 7 What is the most likely websites do you often access to?

		social media	Torrent	commercial	streaming websites	research	All	Total
WHAT IS THE END USER ROLE?	Student	99	26	22	47	13	3	210
	faculty staff	0	0	0	0	4	2	6
	administration staff	0	0	0	0	3	0	3
Total		99	26	22	47	20	5	219

Source: Primary Data, 2020

Table 4.7 the big number of the respondents (99) were accessing social 9media, followed by the respondents (47) most likely website to access to was streaming websites. (26) respondents were accessing torrents and (13) was research with (3) respondents whom were accessing all. Depending on which website the respondents are accessing to, this might affect the network speed because there are some hungry websites that can affect the network easily.

Table 4. 8 At what time do you most likely use campus network?

		morning time	afternoon time	evening time	Total
WHAT IS THE END USER ROLE?	Student	121	48	41	210
	faculty staff	3	2	1	6
	administration staff	0	2	1	3
Total		124	52	43	219

Source: Primary Data, 2020

Table 4.8 the highest number of respondents (124) were using the network in the morning, while (52) respondents were accessing in the afternoon and the minority of the respondents (43) were using the network in the evening. This makes that the higher number of respondents accessing the network the more there is more traffic at this point the network can be affected at this time because of the number of the respondents were accessing this network, therefore at the time that there are few respondents the network should not be much affected as much as when there were many users on the network. Therefore, the network could get affected when there is big number of the end users on the network at the same range of time.

Table 4. 9 What devices do you mostly use for accessing the campus network?

		Phone	tablet	Laptop	campus desktop	Total
WHAT IS THE END USER ROLE?	Student	118	19	26	47	210
	faculty staff	1	0	1	4	6
	administration staff	1	0	1	1	3
Total		120	19	28	52	219

Source: Primary Data, 2020

In Table 4.9 one hundred and twenty (120) respondents were mostly using phone by accessing university network, while fifty two (52) respondents were using campus desktop, twenty eight (28) were using laptops and nineteen (19) were using tablets, this implies that respondents using phones by accessing network could be easily affect the network because by leaving the Wi-Fi on could be connected without even using the phone which is also the factor that affect the network by having much traffic even when the end user is not using the device.

Table 4. 10 What type of campus network do you use to access the network?

		Wireless	wired	Both	Total
WHAT IS THE END USER ROLE?	student	154	45	11	210
	faculty staff	1	4	1	6
	administration staff	2	1	0	3
Total		157	50	12	219

Source: Primary Data, 2020

Table 4.10 the majority of end users (respondents) (157) were using wireless to connect to the network of the university, while (50) were using wired and (12) were on both (wired and wireless). This makes the wireless the most type of network to be more accessed to.

4.4 Objective One: To investigate the End User satisfaction of Enterprise Network at ULB

The study sought to investigate the End User satisfaction of Enterprise Network. Questions on this aspect was asked based on Likert scale and descriptive statistics on this aspect established. Results were presented basing on the means and standard deviations of the statement asked in table 4.10

In order to analyze the satisfaction of the campus network performance, a Likert scale was used to measure the level of end user satisfaction. Therefore, the mean average is given in the following table:

Table 4. 11 percentage from the Responses about the User satisfaction of the Campus Network Speed

HOW DO YOU FEEL WITH THE UNIVERSITY NETWORK SPEED?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very unsatisfied	66	30.1	30.1	30.1
	unsatisfied	44	20.1	20.1	50.2
	neutral	48	21.9	21.9	72.1
	satisfied	54	24.7	24.7	96.8
	very satisfied	7	3.2	3.2	100.0
	Total	219	100.0	100.0	

Table 4. 12 Median, mode and range of Responses about the User satisfaction of the Campus Network

HOW DO YOU FEEL WITH THE UNIVERSITY NETWORK SPEED?

N	Valid	219
	Missing	0
Median		2.00
Mode		1
Range		4

Source: Primary Data, 2020

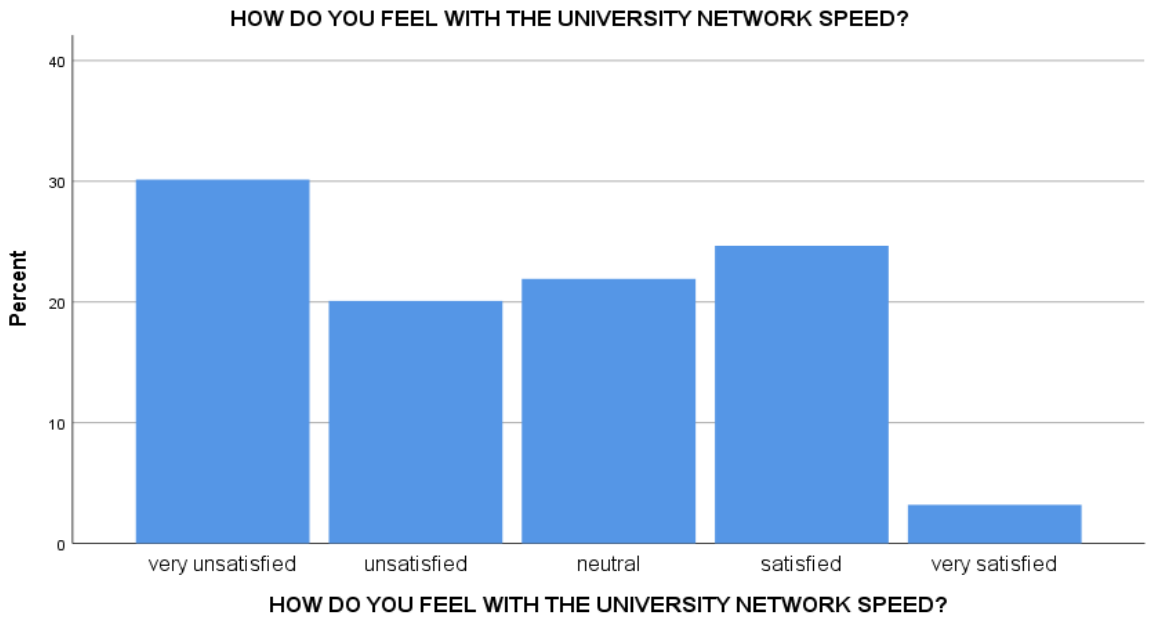

Figure 4. 1 bar chart

The tables above tables 4.11, 4.12 and figure 4.1. present the responses (from the respondents) on the level of agreement regarding the level of end user satisfaction. The most frequently occurring value in data set about the level of end user satisfaction was one which represented the respondents who were very unsatisfied with the enterprise network performance at Université Lumière de Bujumbura that was the mode of the end user satisfaction with the existing network performance without virtual local area network. The median had a value of two which is in the middle of the ordered data set in 2nd position which is unsatisfied with the enterprise network. 30.1% were very unsatisfied, 20.1% were unsatisfied, 21.9% were neutral, 24.7% were satisfied and 3.2% were very satisfied.

The central tendency of ordinal data set is where mostly values lie mode and median are most commonly used to measure the central tendency of ordinal data for measuring the level of end user satisfaction with the existing enterprise network performance using virtual local area network implementation. The bar chart represented the percentage of how respondents responded on the questionnaire that were given out to find out the level of end user satisfaction of the existing enterprise network performance.

The most occurring value was for the respondents who were very unsatisfied with network performance and was easily seen in the bar graph because it was the value with the highest bar.

The respondents were 219 who responded the questionnaire of the objective, about of the level of end user satisfaction on the enterprise network performance. The data that was collected at Université Lumière de Bujumbura, the majority of respondents were not satisfied

with the network, which was very important to implement virtual local area network in the existing network.
Hence, there is a need of analyzing the existing enterprise network performance with virtual local area network implementation.

4.5 Objective two: To identify the drawbacks of existing enterprise network at ULB

The structured interview were the questions responded by the network and system administrators at ULB about the enterprise network structure and all component that are built the ULB. A network administrator was a man according to his responses from a structured interview guide he said*: "I had been there over three years; the internet service provider is Burundi Backbone System (BBS) company which is providing the bandwidth of 6Mbps but for two universities the main campus and the branch on this bandwidth the main campus is using 3 Mbps and the branch is also using 3 Mbps and the network topology is a star topology. the network is slow during peak time due to unsegmented network. the end users who use more bandwidth than others are students. We are using RIP as routing protocol; additionally, there is no user access policies enforced which was allowing user to download or upload at any time, therefore causing lack of bandwidth to user. The entire enterprise network at ULB is built by firewall using cat 6 cable to a 4500 router as gateway and connected to an IP cloud using fiber cable (ppp_28K); there is four switches in two buildings; each switch had 48 ports. in first building there are three labs connected to one switch with cat 6 cable which connects to server switch and the second building there is three switches, one switch connects two LANs one cat 6 goes to all school departments LAN and another goes to lecturer's room LAN and there is administration LAN on other switch which is connected to server switch. There is a server room in second building which had a 48-ports switch connected with three servers is connected to the firewall talked above those servers were web, file and database .in both buildings each switch there is wireless LAN ethernet router that is connected to it except server switch."*

According to the system administrator at ULB, he gave out his point of view of the network performance and he was also a man*: "I have been here over three years, the network has been slow in the morning because of the highest number of students are accessing the network we have three servers are on web, file and database servers their capacities are one*

Tb, two Tb and two Tb respectively there were core i7 and there is also cache memory server but no proxy server."

4.6 Objective three: To Measure the existing enterprise network performance (NO_VLAN)

4.6.1 Implementation of ULB Enterprise Network Design into Riverbed modeler academic edition (OPNET) 17.5

Implementation of enterprise network was simulated by using Reverbed modeler academic edition 17.5 or OPNET (Optimized Network Engineering Tool), which was used for performance analysis and the implementation of network.

The aim of this research was modelling, configurating and performance analysis of the customized network using riverbed modeler (OPNET). Modeler provided high fidelity modeling, scalable simulation and detailed analysis of a broad range of wired and wireless networks with application traffics. The project was presented with the network simulation software Riverbed modeler which is able to efficiently analyze the performance of the protocols and technologies in network infrastructure models of realistic scale.

This section presents the technical setup of an enterprise network which was used to setup the entire network at ULB. In this research, the researcher wanted to find out the difference between the enterprise network performance with VLAN and with no VLAN. This means that enterprise network with VLAN is the independent variable and enterprise network with no VLAN is the dependent variable. As such the implementation in OPNET outlined what happens in enterprise network performance with no VLAN and after VLAN implementation in an enterprise network. This research provides two scenarios, the objective of these scenarios is to compare the performance for enterprise network with VLAN and with no VLAN.

Riverbed modeler academic Edition 17.5 (OPNET) was used to simulate the enterprise network (LAN) and VLAN with different application over the network for comparing the performance of both LAN (NO_VLAN) and VLAN. Two scenarios with VLAN and NO_VLAN communication were tested, discussed and showed the results in the following subsection.

The following tools that were used in the creation of ULB enterprise network

- Ethernet switch
- Wireless routers and ethernet router

- Nodes/100BaseT_LAN
- Ethernet server
- Links (100BaseT and PPP_28K)
- Ip Cloud
- Firewall
- Application Interface
- Profile interface

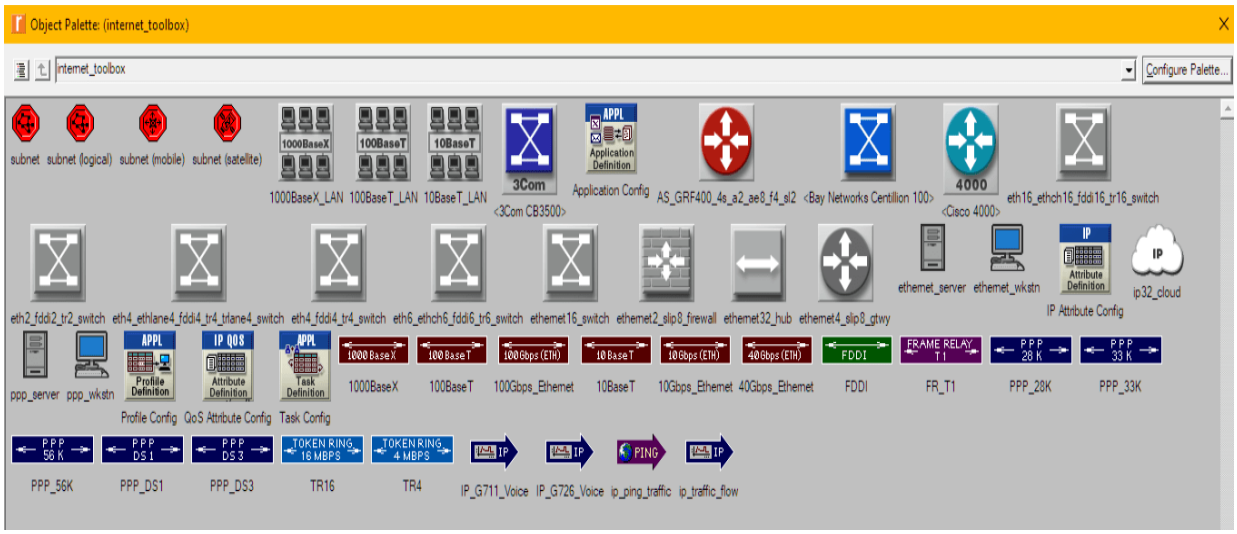

Figure 4.2 shows internet tools box in riverbed modeler

The object palette or internet toolbox shows all tools that are built in reverbed modeler simulation those help in creation of the network simulation.

4.6.2 Simulation of LAN (NO_VLAN) network or Enterprise network for ULB

The first scenario was designed to visualize an enterprise network (NO_VLAN). Though, in two buildings there were four main switching devices, students switch for Students Lan with three Labs in building A and in building B there were departments switch for departments Lan and lecturers room Lan, administration switch for Administration Lan and the servers switch in server room that also connect all three switches (students, departments and administration LANs). A switch forwards the incoming packet to the output ports based on the destination address. In this scenario, there was single broadcasting domain network only. Therefore, users were allowed to access to confidential servers and share all resources. All nodes were communicating each other because there were no restrictions. Therefore, there were much traffic requests on servers.

The ULB enterprise network description for creating sub network with all the requirements:

- The entire network has four subnets -students, departments and administration.
- Students subnet in building A there are three labs connected to a switch (students switch).
- Departments subnet which is in building B there are two LANs, one is for all student departments and another for lecturers' room there are all connected to departments switch.
- Administration subnet located in building B is connected to administration switch.
- All three servers are located in the server room in building B, all those are connected to server switch which connects all the three subnets and also connects to the firewall to gateway through the IP Cloud.

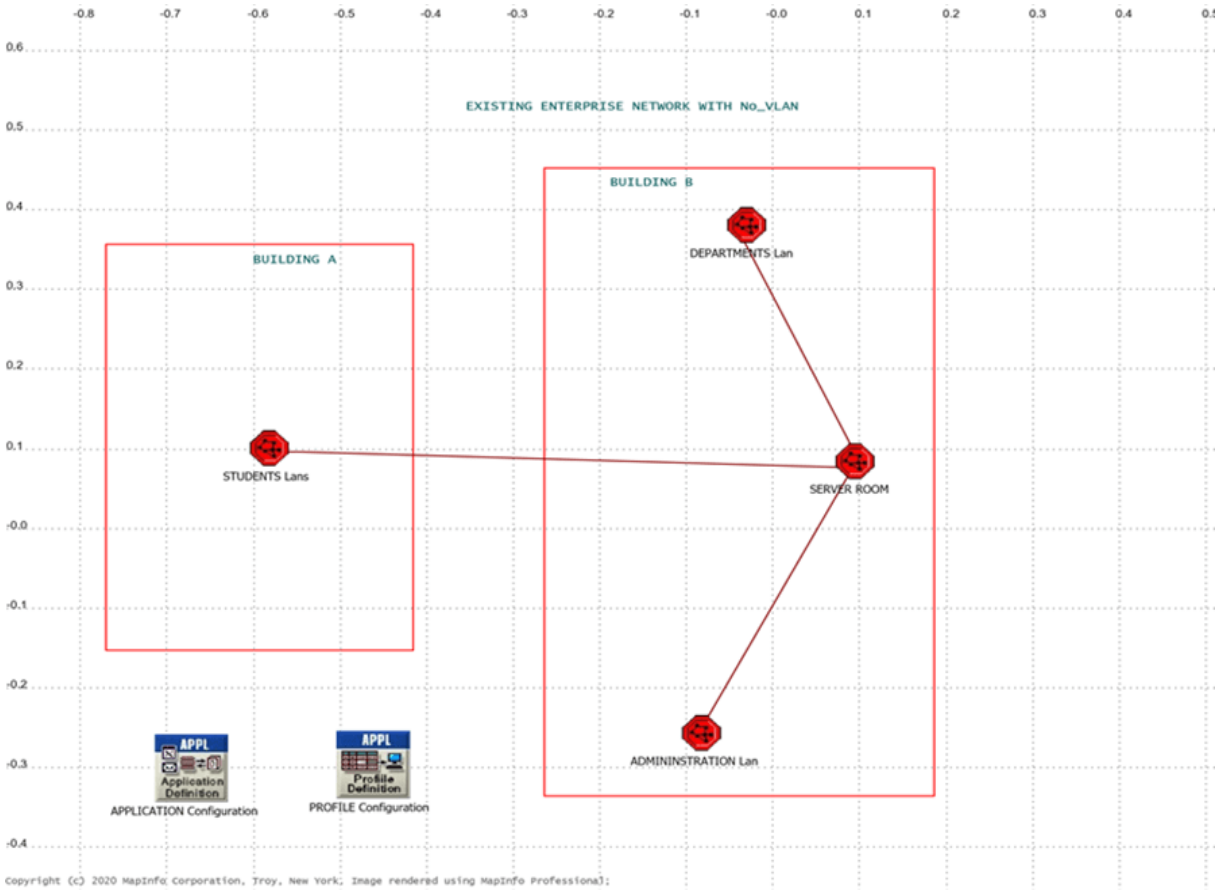

Figure 4. 2 The entire ULB Enhancement Enterprise Network with NO_VLAN

Figure 4.3 shows that there were two buildings A and B, they had different hosts classified but all had a wireless access point as students Lan which had 3 labs and wireless access point in building A and Departments Lan had two subnetworks lecturers room Lan and

departments Lan and wireless access point, administration Lan and wireless access point in building B had one subnet in administration and server room which was in building B had 3 servers with the server switch which connected all the subnets in building A and B

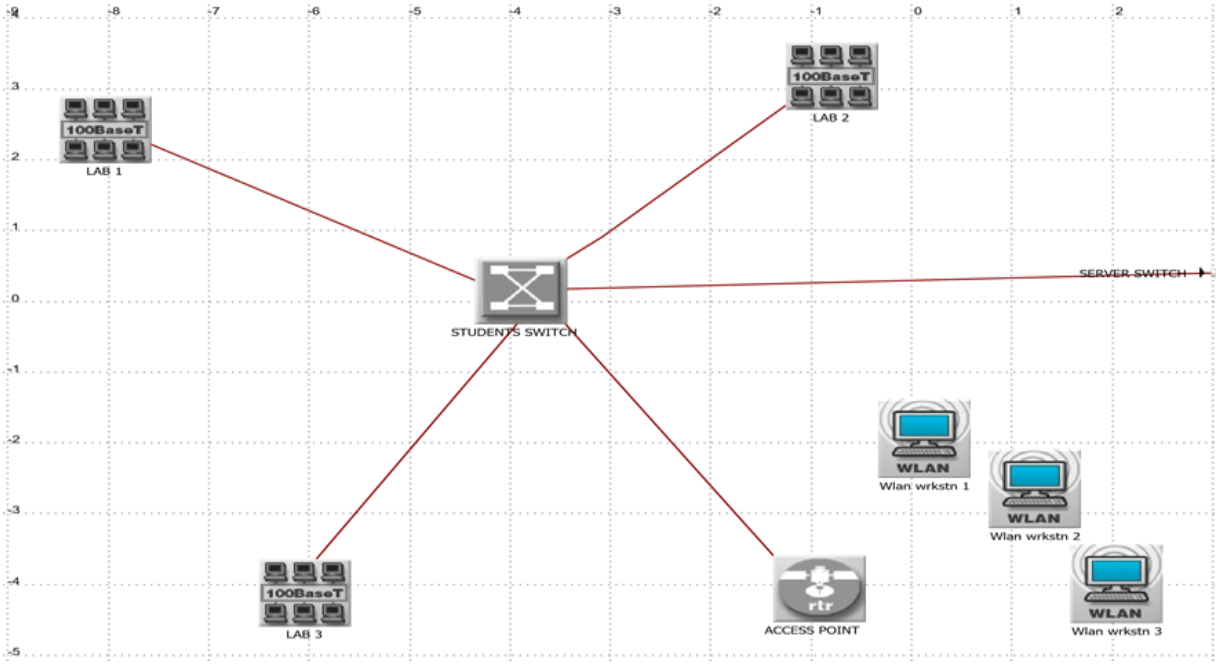

Figure 4.4 students Lan subnet with NO_VLAN

The figure 4.4 shows the students subnet LAN with NO_VLAN, it was well explained in the table below table 4.13.

Four LANs created in Students LAN -LAB 1, LAB 2, LAB 3 and wireless access point of ULB enterprise network configured the network elements as described in the table below

Table 4.13 Students Lan subnet with NO_VLAN network elements

Students Lan subnet	workstation	Link to SWITCH/WLAN Router	Central node for the LAN
LAB 1	100BaseT LAN	100BaseT	Ethernet48_switch
LAB 2	100BaseT LAN	100BaseT	
LAB 3	100BaseT LAN	100BaseT	
wireless access point	WLAN workstation Mobile Node)	Wireless Link	WLAN_ethernet_router

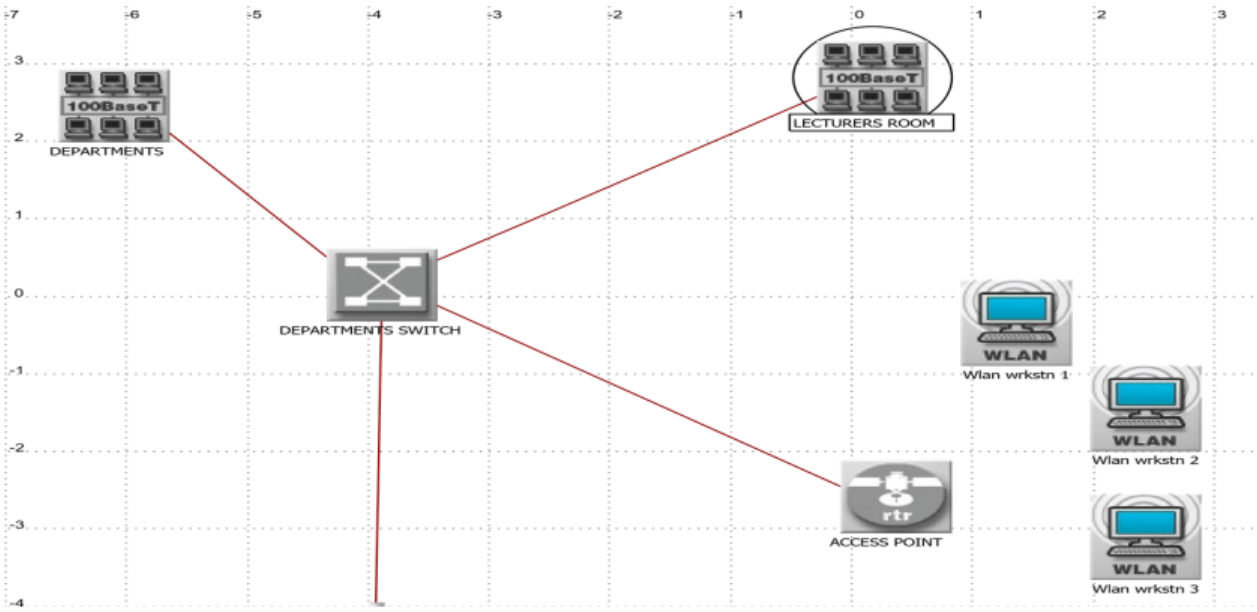

Figure 4.5 Departments Lan subnet with NO_VLAN

The figure 4.5 is well explained in the table below 4.14.

Three LANs created in Departments LAN subnet -Departments LAN, Lecturers' Room and wireless access point of ULB enterprise network configured the network elements as shown in the table below.

Table 4. 13 Departments Lan subnet with NO_VLAN network elements

Departments Lan subnet	Workstation	Link to SWITCH/WLAN Router	Central node for the LAN
Departments LAN	100BaseT LAN	100BaseT	Ethernet48_switch
Lecturers' Room	100BaseT LAN	100BaseT	
wireless access point	WLAN workstation (Mobile Node)	Wireless Link	WLAN_ethernet_router

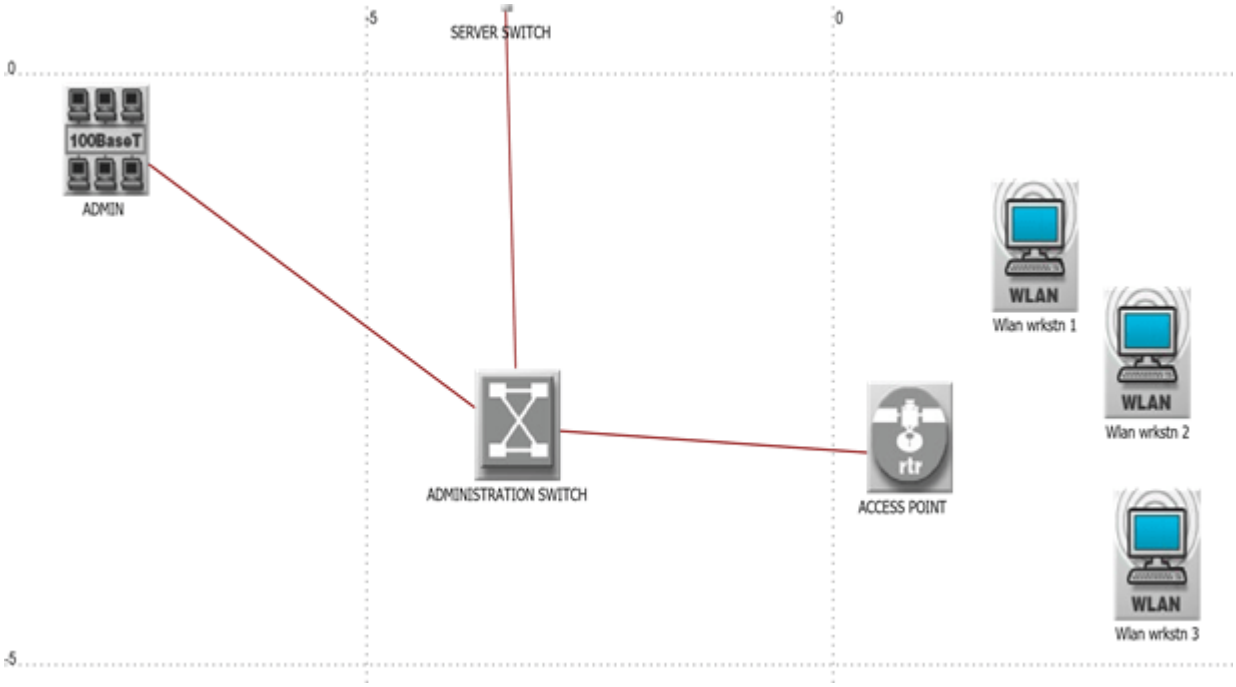

Figure 4. 3 Administration Lan with NO_VLAN

Two LANs created in Administration LAN subnet – Administration LAN and wireless access point of ULB enterprise network configured the network elements as shown in the table below

Table 4. 14 Administration Lan subnet with NO_VLAN network elements

administration Lan subnet	Workstation	Link to SWITCH/WLAN Router	Central node for the LAN
Administration LAN	100BaseT LAN	100BaseT	Ethernet48_switch
Wireless access point	WLAN workstation (Mobile Node)	Wireless Link	WLAN_ethernet_router

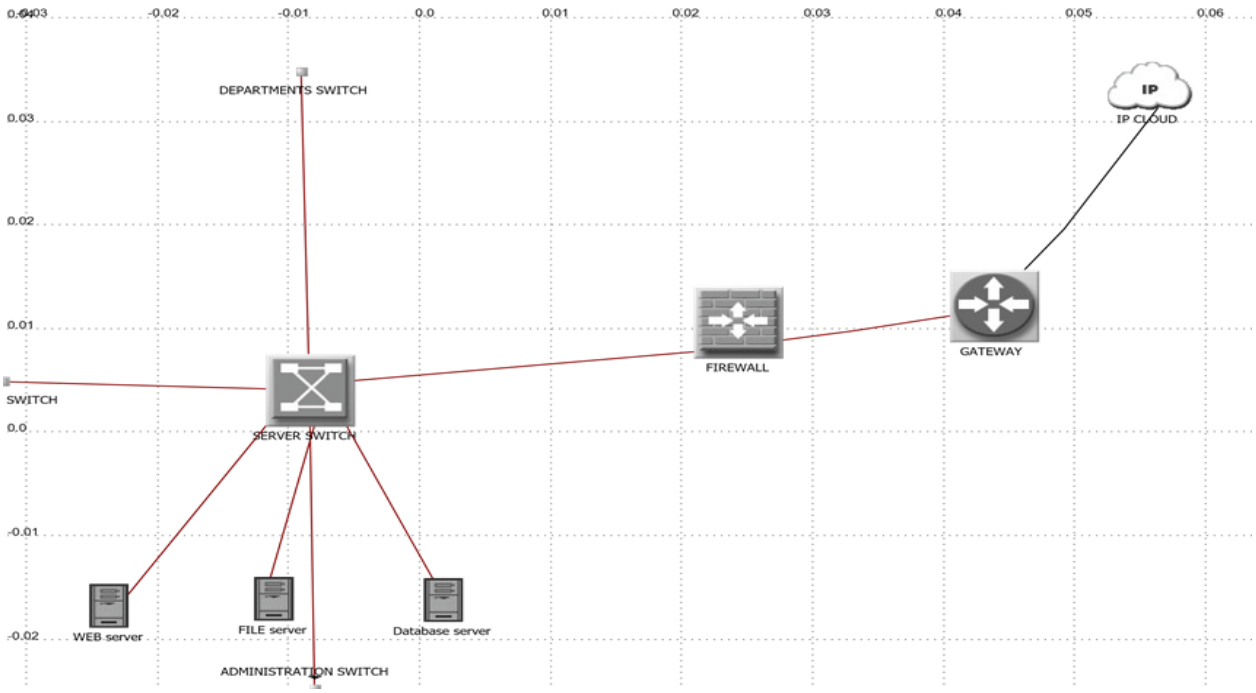

Figure 4.7 server room with NO_VLAN

Table 4. 15 Server Room Lan subnet with NO_VLAN network elements

Server Room subnet	Link to SWITCH/Router/firewall/ Ip cloud		Central node for the LAN	Connected to FIREWALL to GATEWAY to IP CLOUD
WEB server	100BaseT	PPP_28K	Ethernet64_switch	
FILE server	100BaseT			
Database server	100BaseT			

This table above 4.16 explained the components that are built the server room with NO_VLAN in the figure 4.7 above.

This figure 4.7 has shown the entire server room components network at Université Lumière de Bujumbura, As it was described above, it had four subnets with four LANs in the subnet of students Lan with three labs and a wireless access point in building A and three LANs in departments subnet which were departments Lan, lecturers room Lan and wireless access point, in administration Lan subnet had two LANs; both administration and departments subnets are located in building B and in both subnets there were wireless access points. server room was also located in building B, it had a subnet of three servers (WEB, FILE and Database) with were connected to the core ethernet64_switch to firewall and gateway

connected to an Ip cloud. The CISCO router was used to router information for the entire ULB network used store and forward routing. The router connected to the firewall and to the IP cloud with the help of a PP28 link.

4.6.3 ULB enterprise network configuration parameters

4.6.3.1 Application configuration parameters

In Model every object (application, profile, node and server) had a different and specific set of parameters. Generally, application parameter was an application attribute definition that was used to specify the required application among the available applications such as FTP, HTTP, DATABASE. applications attribute that was created to produce the traffic on this ULB network, there were three applications in both scenarios as FTP (File Transfer Protocol), HTTP (Hypertext Transfer Protocol) and DATABASE application. Applications performance was used with both NO_VLAN and VLAN scenarios.

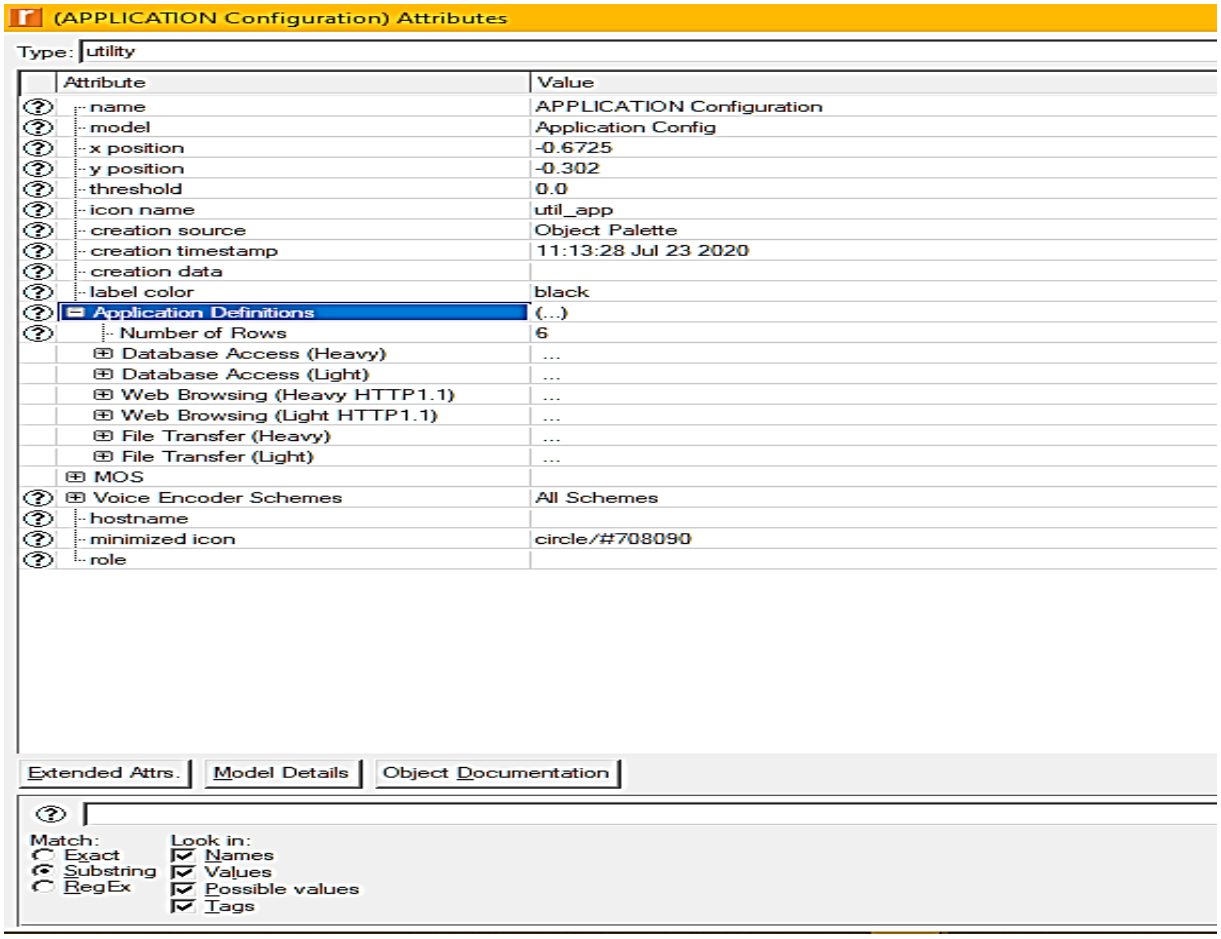

Figure 4. 4 Application configuration

The applications configurations which are in the figure 4.8 are well explained below one by one in the figures below. Applications helps the simulation to create the simulation results through the applications that are running on both clients and servers.

4.6.3.2 Profile configuration parameters

Profile parameter was used to create user profiles/client, these profiles were specified on different nodes/LANs in the network designed to generate the application traffic, profile configuration described as the activity of application which used by users throughout a time period. Students clients, Department clients and administration clients were used as profiles on HTTP, FTP, DATABASE as application, they were used in sever (Web, File and Database) parameters respectively to support the services that being requested by the clients. All profiles were configured to run together to allow more than one application to work at same time.

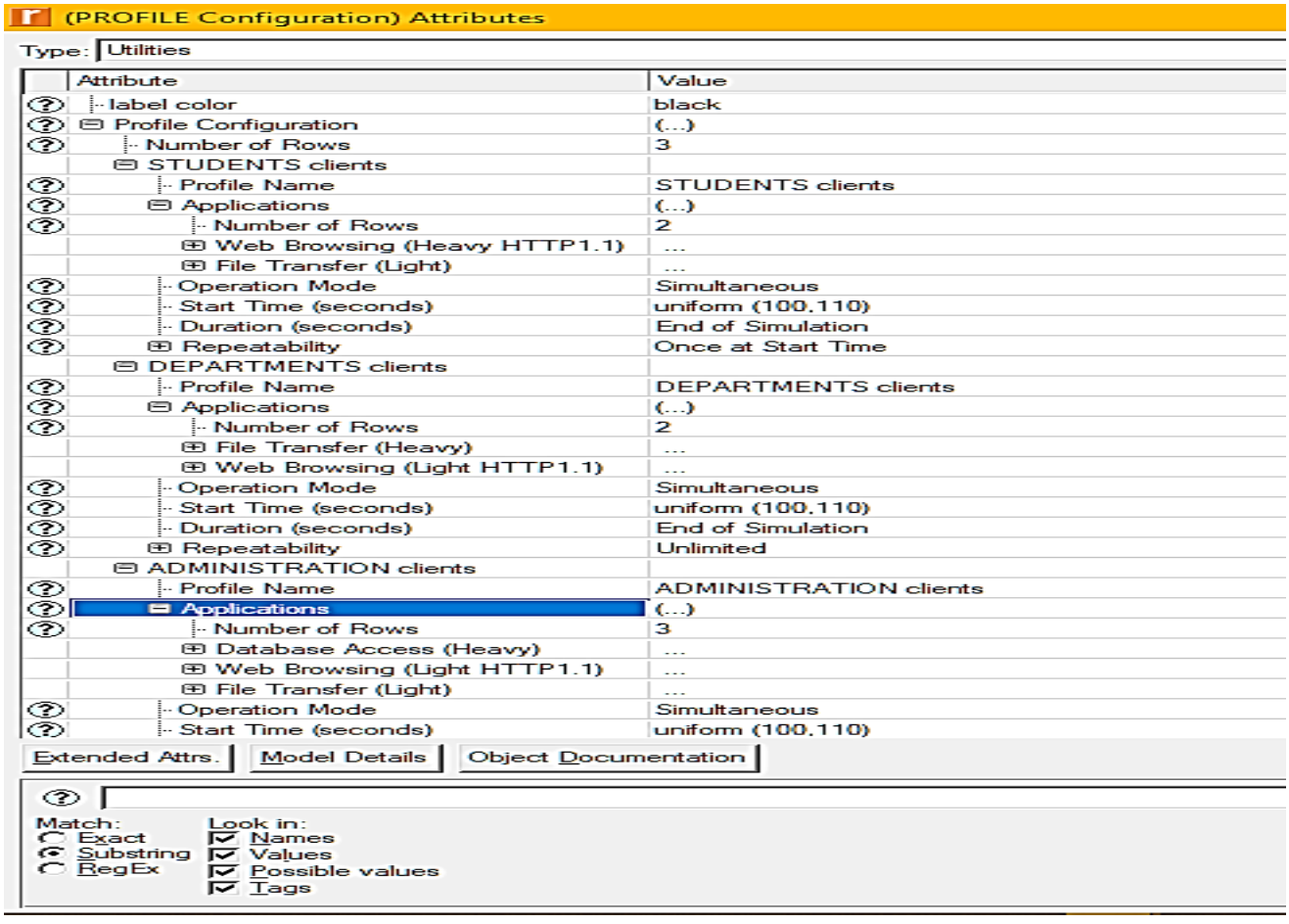

Figure 4. 5 Profile configuration

4.6.3.3 Servers configuration parameters

Server parameters in each server supported services that are based on the user profiles that support HTTP, FTP and DATABASE. The profile configuration was defined in clients as students, departments, administration clients, this configuration profiles helps the clients to receive the services from the servers that are being requested by the clients.

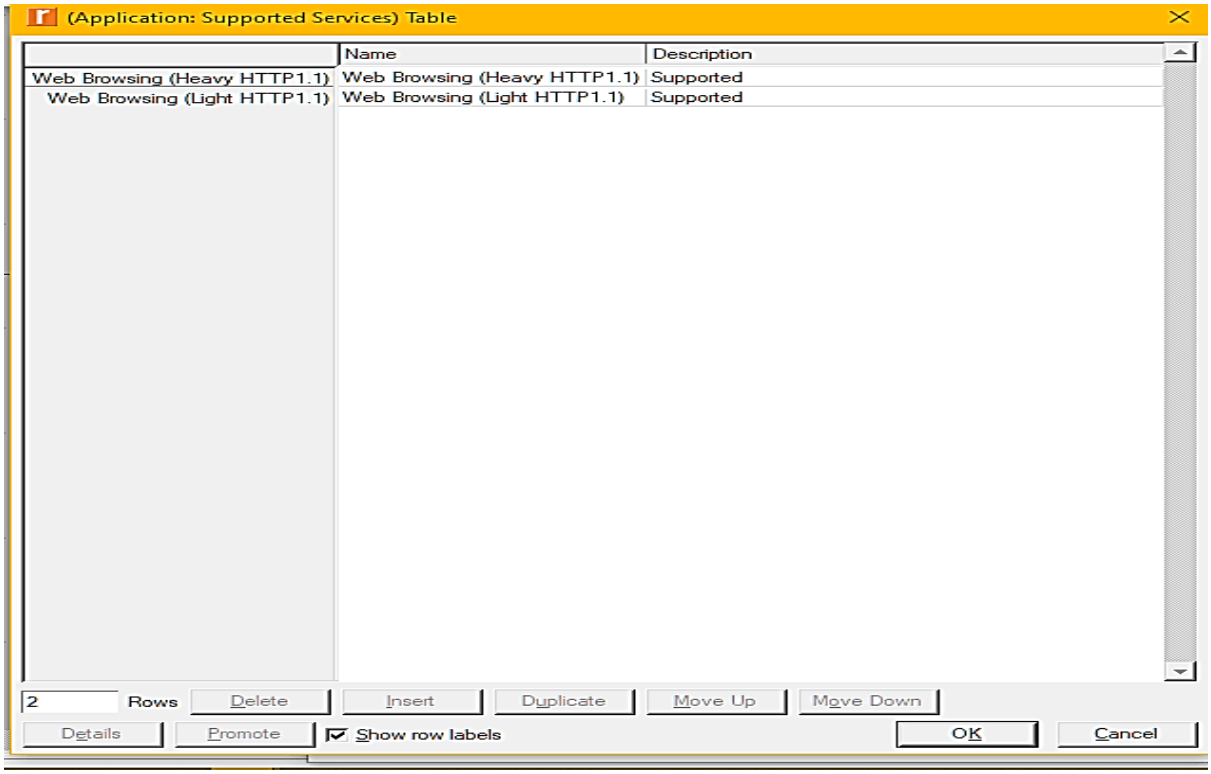

Figure 4. 6 Web server configuration

WEB server was configured to run the HTTP services by right clicking on the server model and choose: edit attributes-application supported services-HTTP server. the web server was running both heavy and light web browsing traffic, this was illustrated in the figure above.

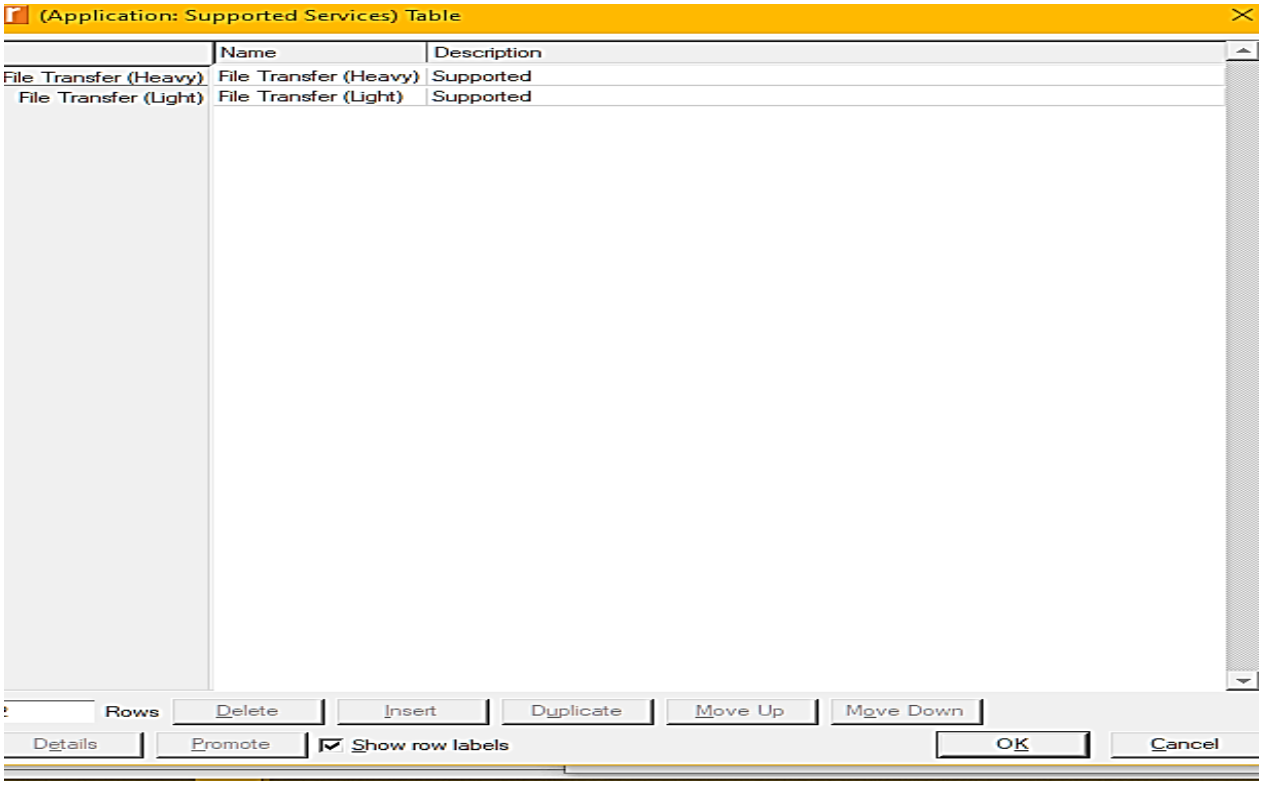

Figure 4. 7 File server configuration

FILE server was configured to run the FTP services by right clicking on the server model and choose: edit attributes-application supported services-FTP server. The file server was running both heavy and light file transfer traffic, this illustrated in figure above.

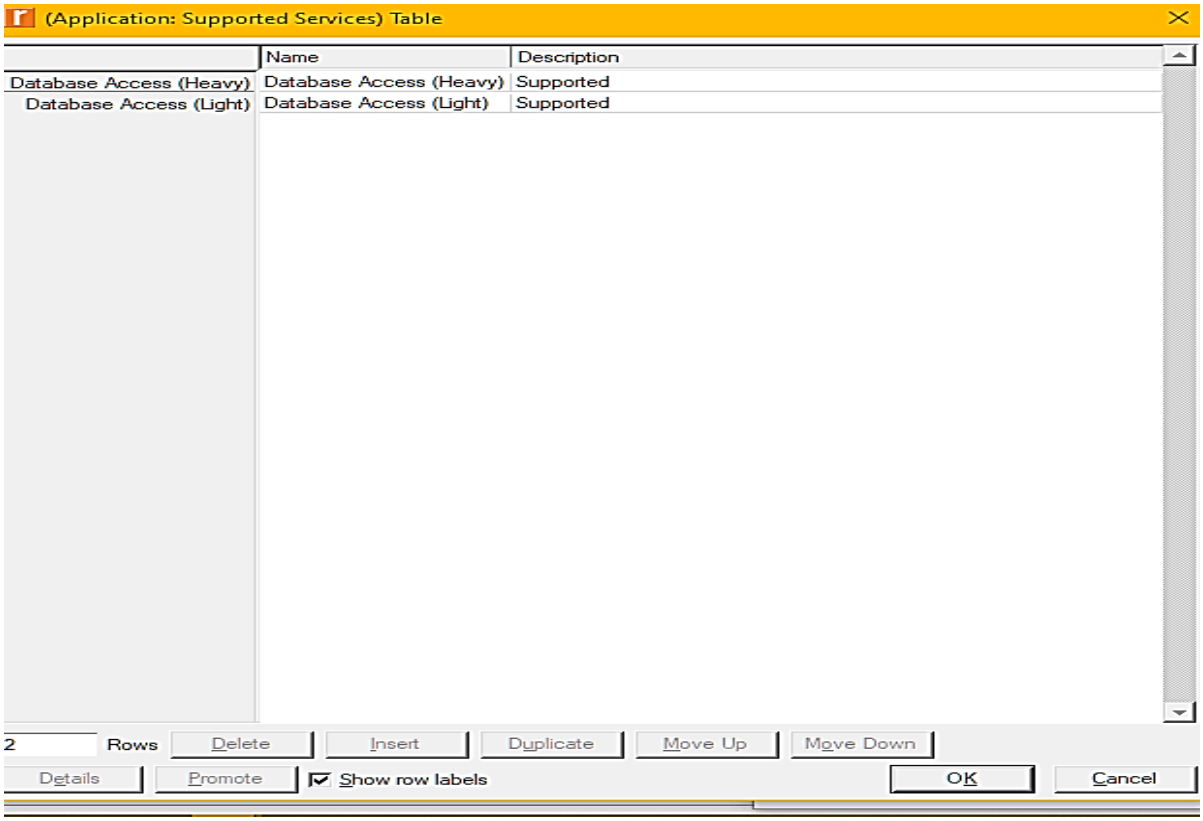

Figure 4. 8 Database server configuration

Figure 4.12 Database server was configured to run the database services by right clicking on the server model and choose edit attributes-application supported services-database server. Database server was running both heavy and light traffic, this was illustrated in the figure above.

4.6.3.4 Clients configuration parameters

LANs Parameters (PC) was a network parameter that were set for all nodes, such as 100BaseT with server applications, this allows the LANs configuration to run profile which contain the applications which generated the traffic by getting the request from the servers. The servers provide services that were being requested by the clients by passing through the switches to the link.

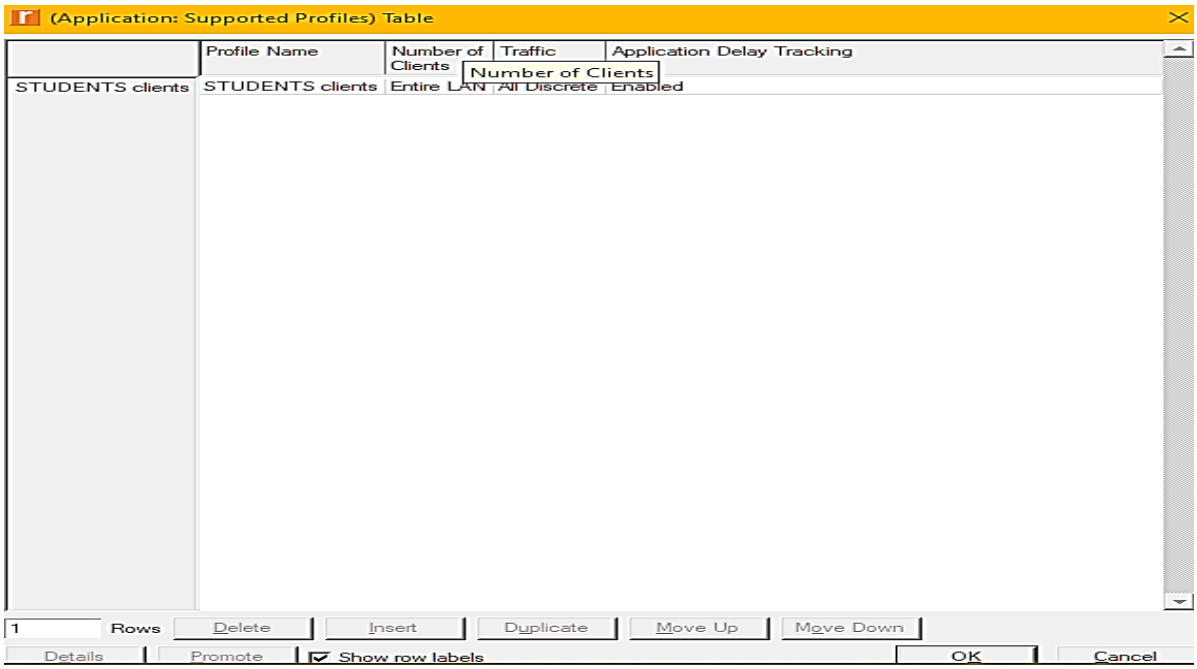

Figure 4. 9 students Lan configuration with NO_VLAN

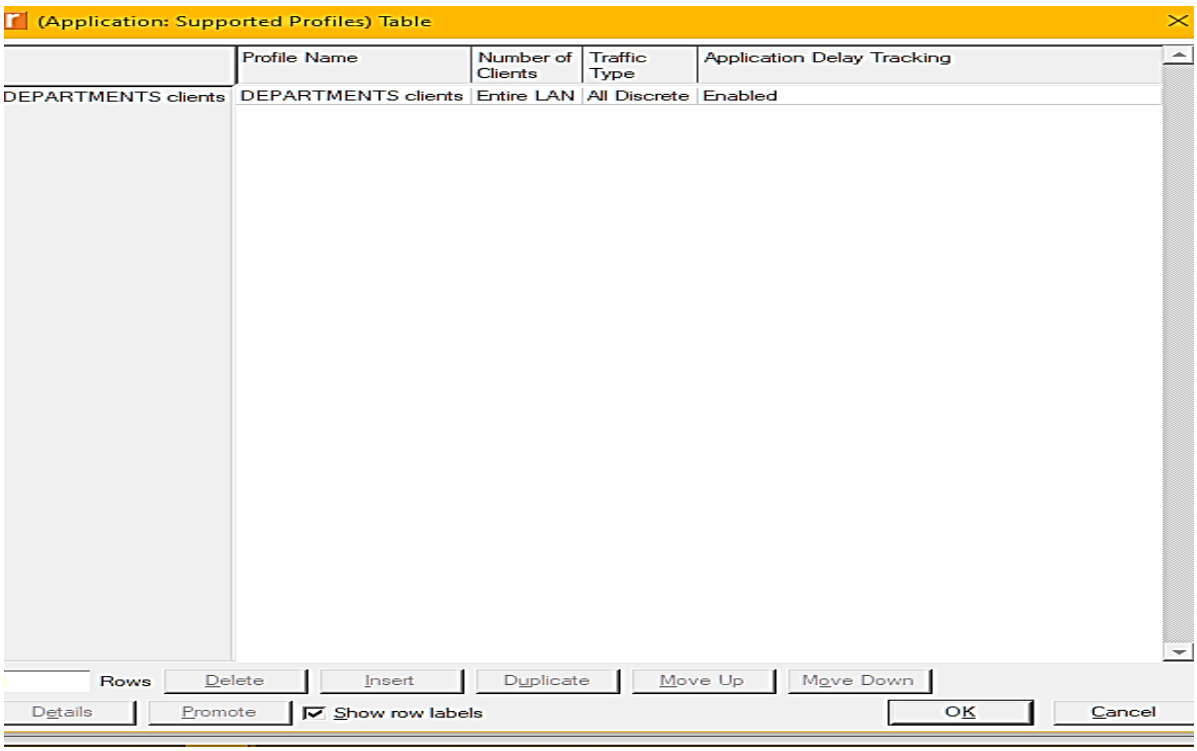

Figure 4. 10 Departments Lan configuration with NO_VLAN

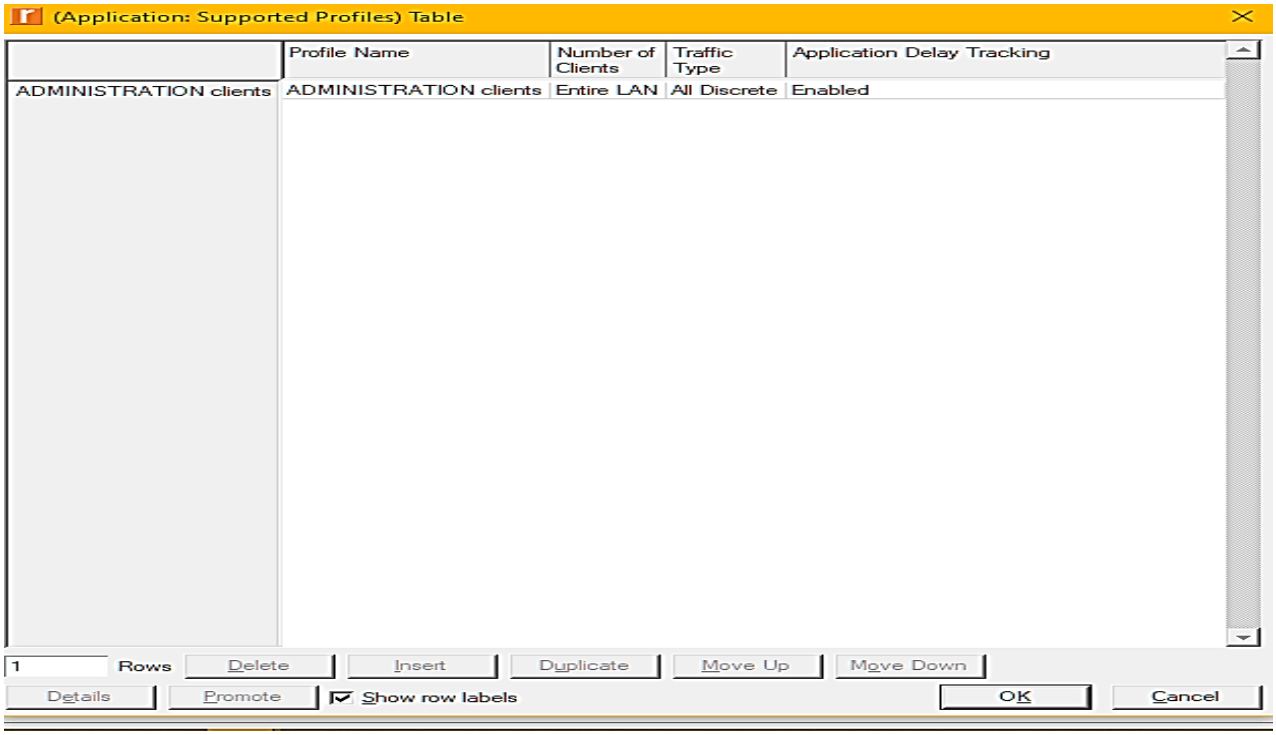

Figure 4. 11 Administration Lan configuration with NO_VLAN

4.6.4 Results and Graphs

After configuration in the ULB enterprise network with NO_VLAN, the chosen program for the global statistics and individual statistics and ethernet with parameters like Traffic sent/received for Database, HTTP and FTP. page response time was for HTTP this is the time the page takes to bring the results for the server; therefore, the download/upload response time was used to FTP and others downloads and response time for database. The queuing delay for forwarded and received traffic was used for object statistics.

4.6.4 Global statistics simulation results for ULB enhancement enterprise network with NO_VLAN

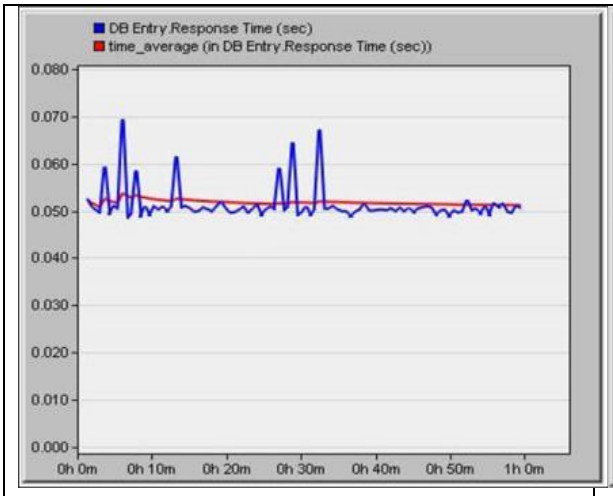

Figure 4. 12 Database Entry response time (sec)

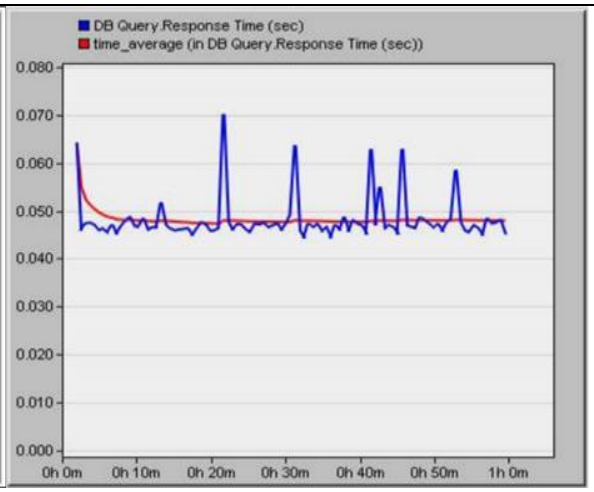

Figure 4. 13 Database Query response time(sec)

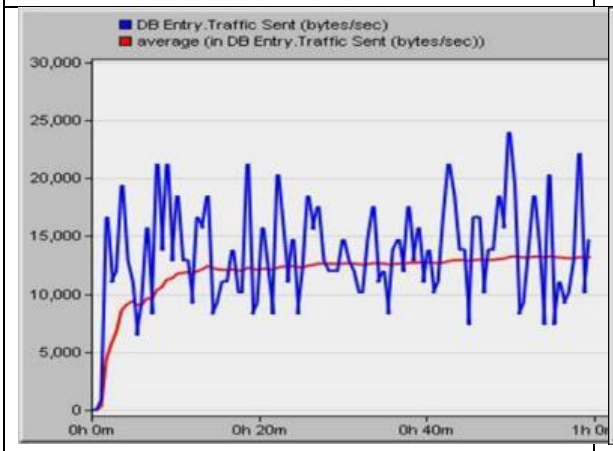

Figure 4. 14 Database Entry traffic sent(bytes/sec)

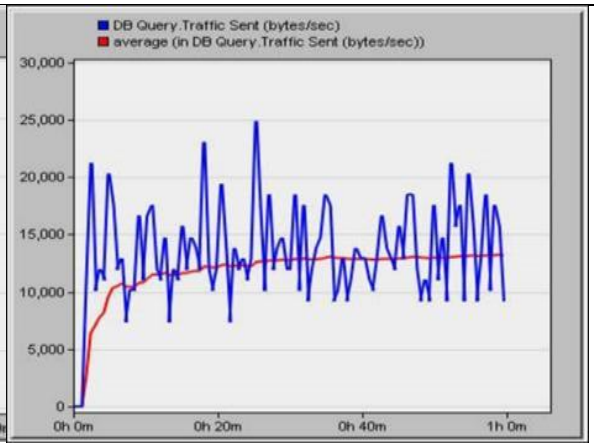

Figure 4. 15 Database Query traffic sent(bytes/sec)

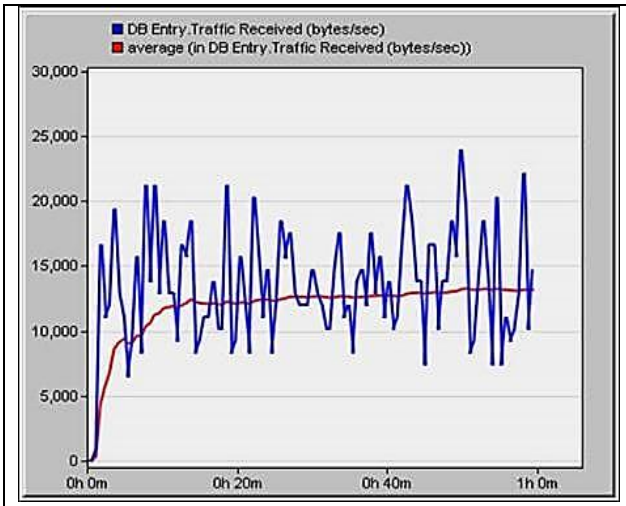

Figure 4. 16 Database Entry traffic Received(bytes/sec)

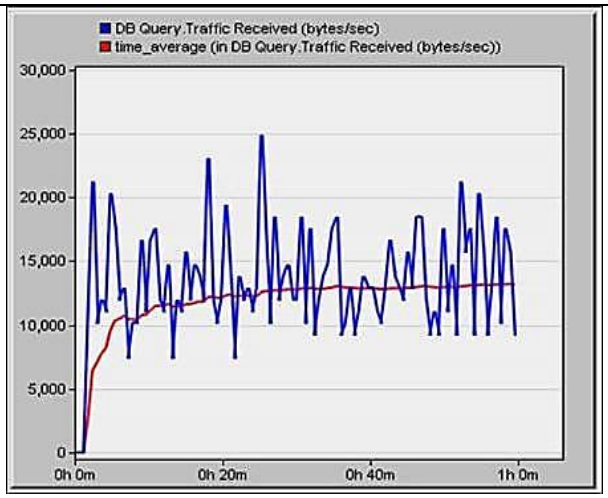

Figure 4. 17 Database Query traffic Received(bytes/sec)

Table 4. 16 Database entry and query with NO_VLAN global statistic data

Global statistics	**Minimum**	**Maximum**	**Average time**
1. DB Entry response time (sec)	0.0485985062868	0.0694791734469	0.0511945834623
2. DB Query response time(sec)	0.0444101892368	0.0701269191489	0.0479528663348
3. DB Entry traffic sent(bytes/sec)	0.0	24,035.5555556	13,164.0888889
4. DB Query traffic sent(bytes/sec)	0.0	24,960	13,182.5777778
5. DB Entry traffic Received (bytes/sec)	0.0	24,035.5555556	13,164.0888889
6. DB Query traffic Received(bytes/sec)	0.0	24,960	13,182.5777778

In the table 4.17 explains the figures above with the simulation results of global statistics at ULB enterprise network using those values that represent the simulation. it showed that traffic sent and received in database query and entry were the same but the response time for database entry and query were different. In database entry response time, the minimum and average time results were higher than database query response time, but maximum database query response time was higher than the entry response time.

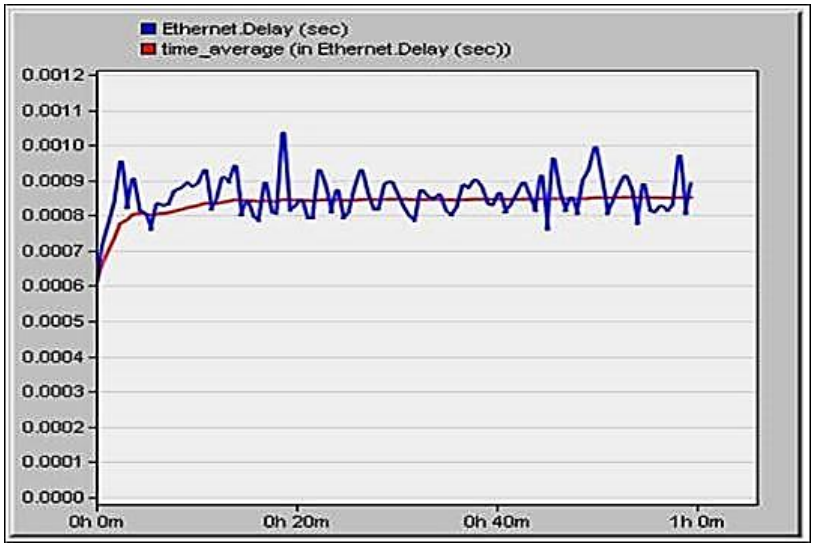

Figure 4. 18 Ethernet Delay (sec)

Table 4. 17 ethernet delay with NO_VLAN global statistic data

Global statistics	**Minimum**	**Maximum**	**Average time**
7. Ethernet delay (sec)	0.00060685468432	0.00103659364566	0.000850873310869

This *Table 4.18* interprets the figure 4.22 showed the global statistics simulation results of ULB enterprise network performance for all applications on this entire network. the red curve showed average time delay and the blue curve showed the ethernet delay which is measured in second, the ethernet delay showed the performance of the time delay of the global statistics for ULB enterprise network.

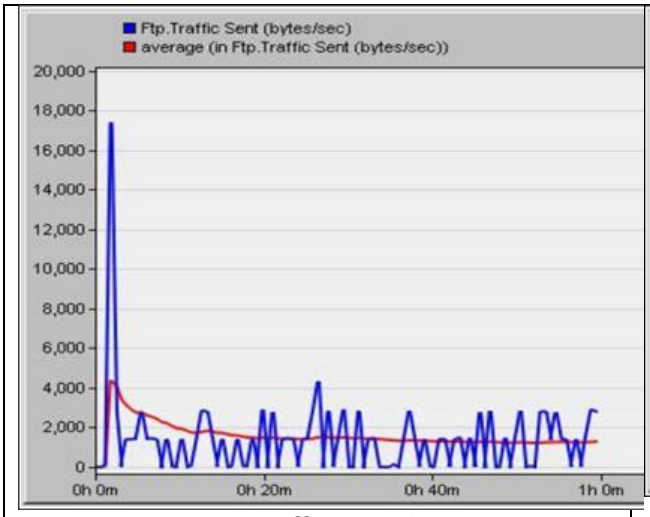

Figure 4. 19 FTP traffic sent (bytes/sec)

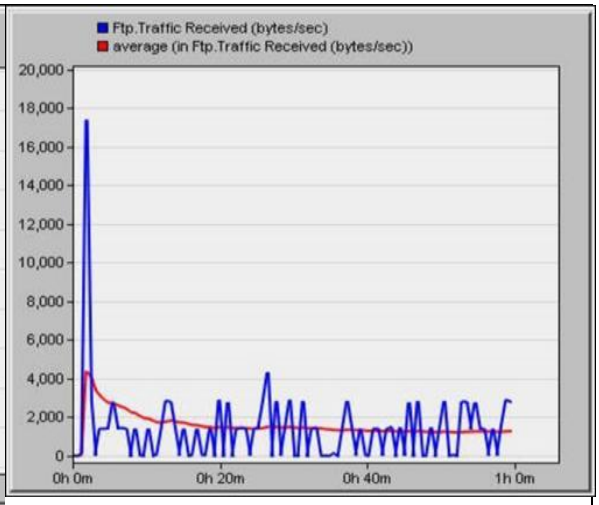

Figure 4. 20 FTP traffic received (bytes/sec)

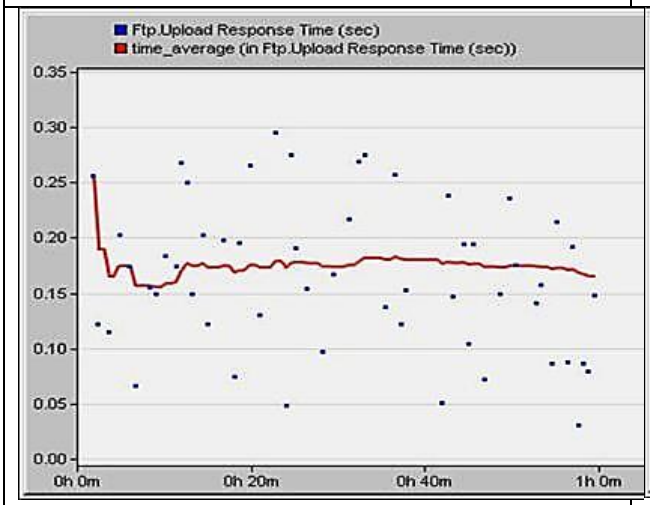

Figure 4. 21 FTP upload response time(sec)

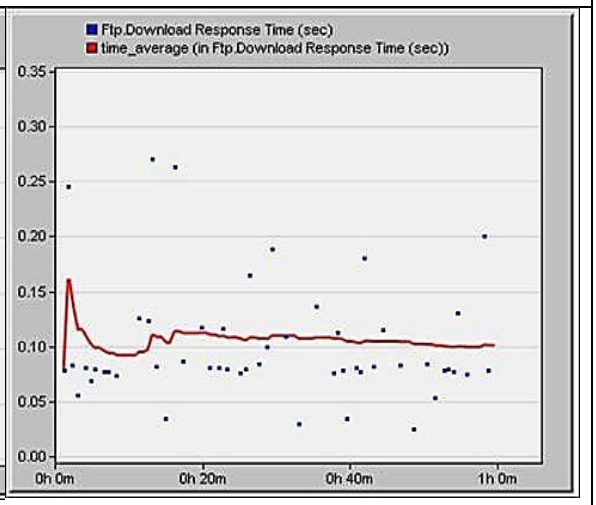

Figure 4. 22 FTP download response time(sec)

Table 4. 18 FTP global statistic data with NO_VLAN

Global statistics	**Minimum**	**Maximum**	**Average time**
8. FTP traffic sent (bytes/sec)	0.0	17,408.2222222	1,280.93777778
9. FTP traffic received (bytes/sec)	0.0	17,408.2222222	1,280.93777778
10. FTP download response time(sec)	0.0253783996459	0.270075329652	0.10090825247
11. FTP upload response time(sec)	0.0308728549885	0.295512491191	0.165057092442

Global statistics results presented in *Table 4.19* interprets the figures above of traffic sent and received (bytes/ sec) showed the same results in the minimum, maximum and average for both sent and received traffic. However, FTP upload response time (sec) took higher response time than FTP download response time.

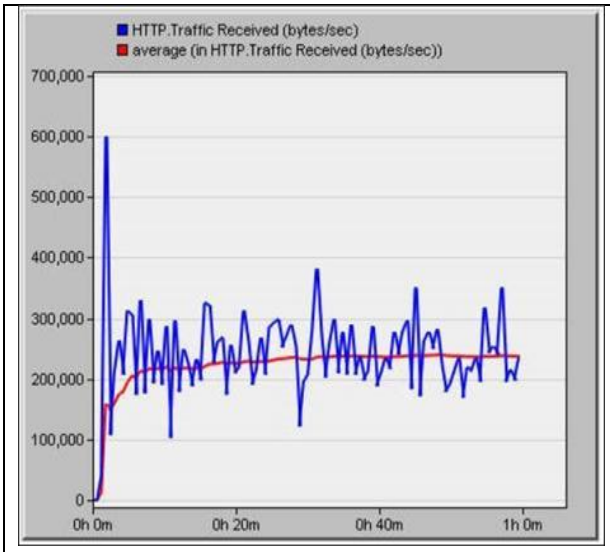

Figure 4. 23 HTTP traffic received (bytes/sec)

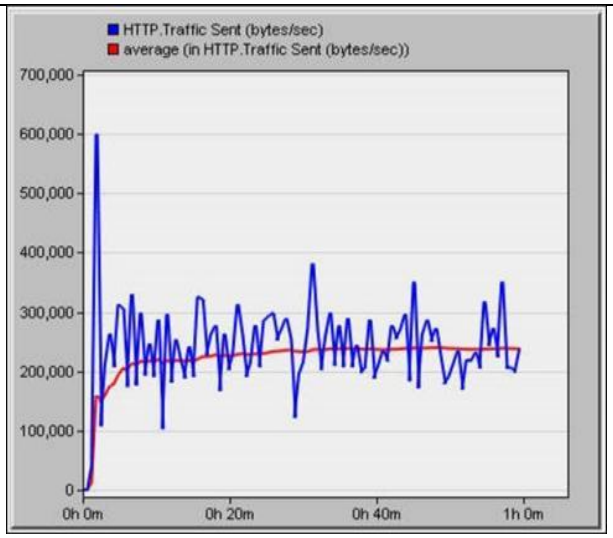

Figure 4. 24 HTTP traffic sent (bytes/sec)

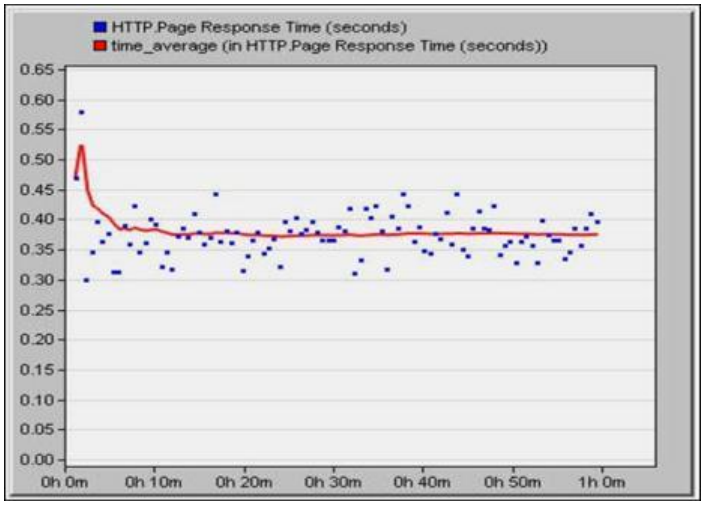

Figure 4. 25 HTTP page response time(sec)

Table 4. 19 HTTP with NO_VLAN global statistics data

Global statistics	**Minimum**	**Maximum**	**Average time**
12. HTTP page response time(sec)	0.299969619033	0.578671187558	0.374898135245
13. HTTP traffic received (bytes/sec)	0.0	599,544.472222222	237,261.350555556
14. HTTP traffic sent (bytes/sec)	0.0	599,626.583333333	237,663.281944444

In this *Table 4.20* explains the figures 4.27,28 and 29 values on the global statistics simulation results of the hypertext transfer protocol page response time (sec) from minimum to maximum has taken almost twice time of the response time. The traffic sent (bytes/sec) was higher than traffic received in HTTP and traffic received and sent has almost the same simulation statistic data, they were all started form zero.

4.5.5 Object statistics simulation results for ULB enhancement enterprise network with NO_VLAN

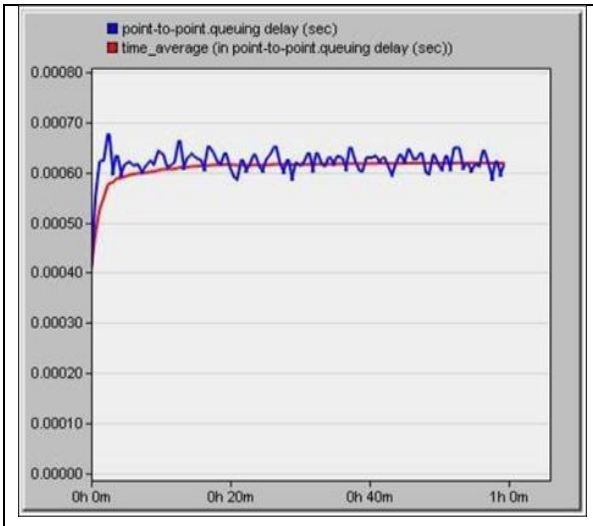

Figure 4. 26 Students queuing delay (sec) →

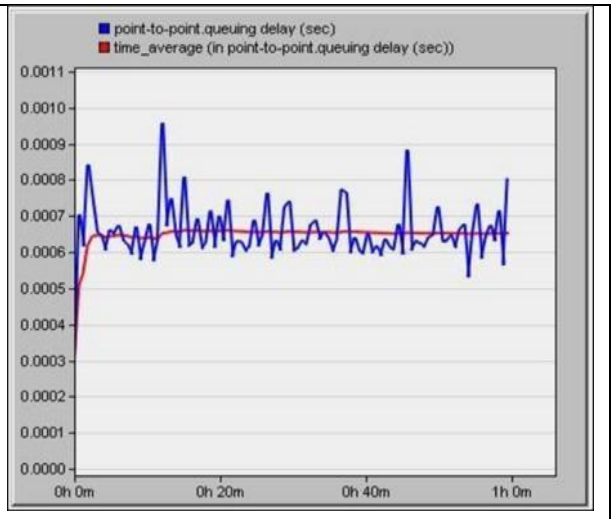

Figure 4. 27 Departments queuing delay (sec)→

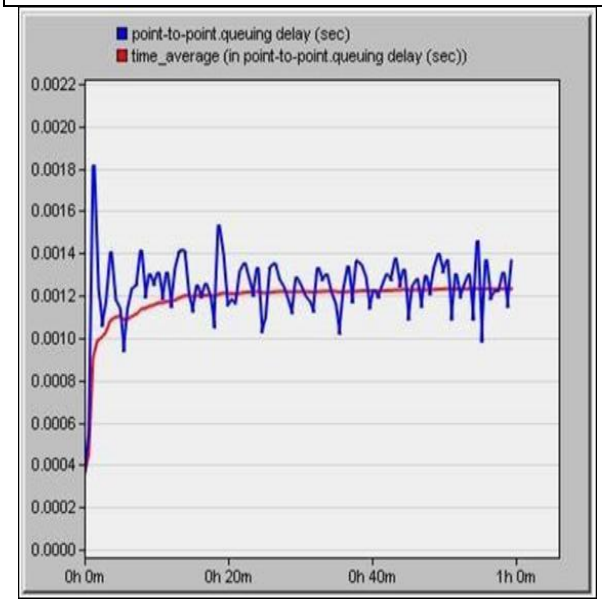

Figure 4. 28 Administration queuing delay (sec)→

Table 4. 20 Queuing delay →(forwarded traffic) object statistics data

Object statistics	Minimum	Maximum	Average time
1. Students queuing delay (sec)→	0.000406039687747	0.000678808086534	0.000618223996928
2. Departments queuing delay (sec)→	0.000307575550157	0.000957151456589	0.000652453623063
3. Administration queuing delay → (sec)→	0.00035489299559	0.00182003452083	0.00123289451776

The table 4.21 interprets the figures above 4. 30,31 and 32 in the object statistics for the outgoing data students queuing delay took much minimum time on the entire network

followed by administration queuing delay and last the departments subnetwork queuing delay, however the administration subnetwork has higher queuing delay, the next is departments subnetwork and students has the lower queuing delay than the rest. Therefore, average queuing delay time is respectively as the previews of maximum queuing delay, start with administration, departments and students queuing delay.

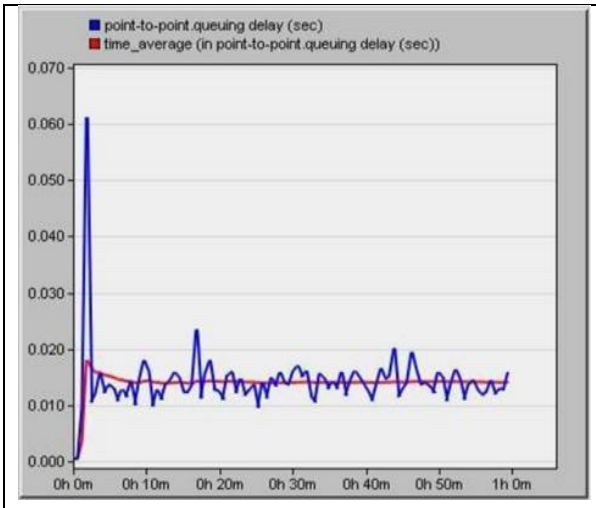

Figure 4. 29 Students queuing delay (sec)←

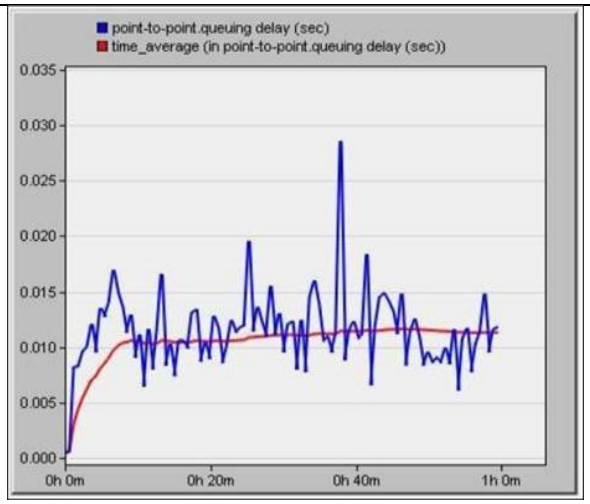

Figure 4. 31 Departments queuing delay (sec)←

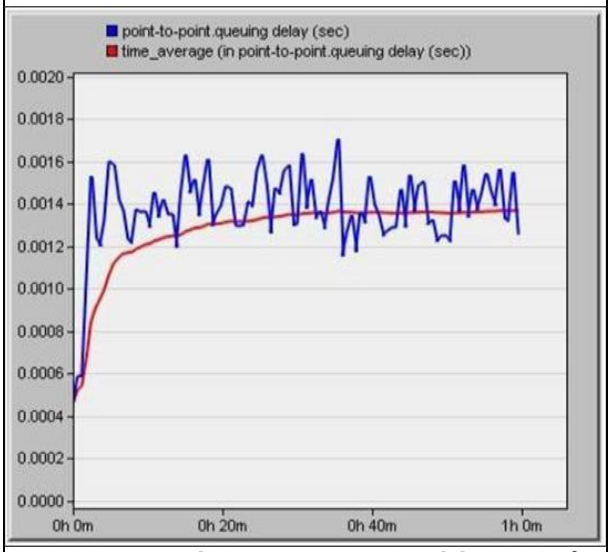

Figure 4. 30 Administration queuing delay (sec) ←

Table 4. 21 Queuing delay ← (received traffic) object statistics data for NO_VLAN

Object statistics	**Minimum**	**Maximum**	**Average time**
4 Students queuing delay (sec)←	0.000415082581562	0.0611603429427	0.0140558169895
5 Departments queuing delay (sec)←	0.000497926177654	0.0286341656191	0.0113112253334
6 Administration queuing delay (sec)←	0.000461776637034	0.00170705905103	0.0013686007295

The table 4.22 interprets the figures 4.33,34 and 35 For the incoming data for the object statistics data, the departments queuing delay had the highest minimum time, the administration queuing delay came the second for the higher number and the last is students queuing delay for incoming or received statistics data. For the maximum students queuing delay took much time followed by departments queuing delay and the lowest maximum queuing delay were for administration, but the average time object statistics data the students took much average time than the others. The departments had the second higher and the lowest was the administration queuing delay time, once there is much data traffic on maximum object statistics there should be a queuing delay is higher.

4.7 Rectification of the drawbacks for the existing enterprise network performance using virtual local area network.

4.7.1 Simulation of VLAN or Enterprise network with VLAN implementation for ULB

The second scenario was designed to visualize the VLAN implementation in the network.

VLAN scenario was the duplication scenario from NO_VLAN scenario (IEEE802.3 protocol) which was added in VLANs (IEEE802.1Q protocol) configuration considered with three logical group of users, which were found in those two different buildings (A and B). These users (students, departments and administration) were logically segmented for the purpose of network performance and security reason by using IEEE802.1Q VLAN protocol. Therefore, the results visualize the influence of different protocols on traffic sent and received, queuing delay, response time, average time and application performance. different VLANs such as students, departments and administration Lan subnetworks, VLAN scenario has segregated a single large broadcasting domain into three broadcasting domains in order to reduce congestion and control traffic sent and received of the network. VLAN network technology was used to improve vulnerability surface for hackers by reducing the traffic request to servers. which were defined in scenario as shown in Table 4.22.

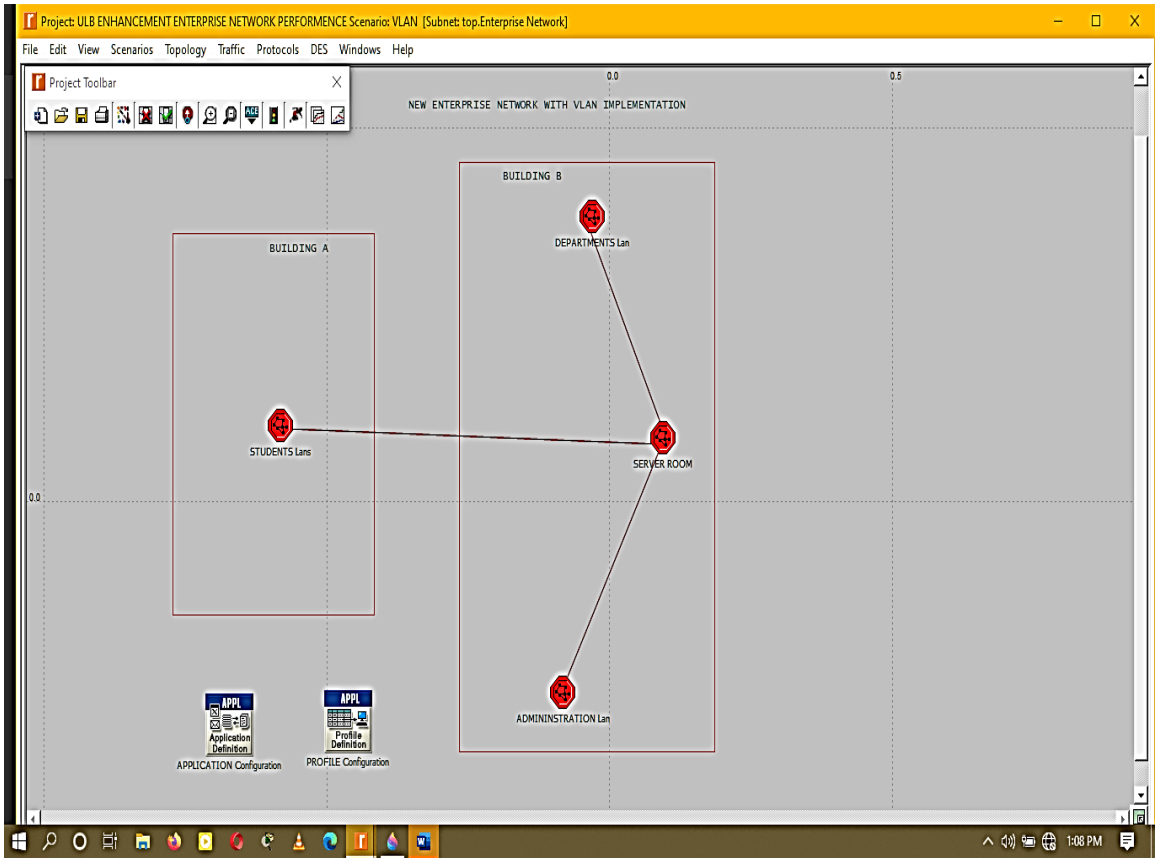

Figure 4. 32 New enterprise network with VLAN implementation

The figure 4.36 represents the entire network with implementation with VLAN on both building A and B at ULB campus network in Riverbed Modeler Academic Edition 17.5 (OPNET)

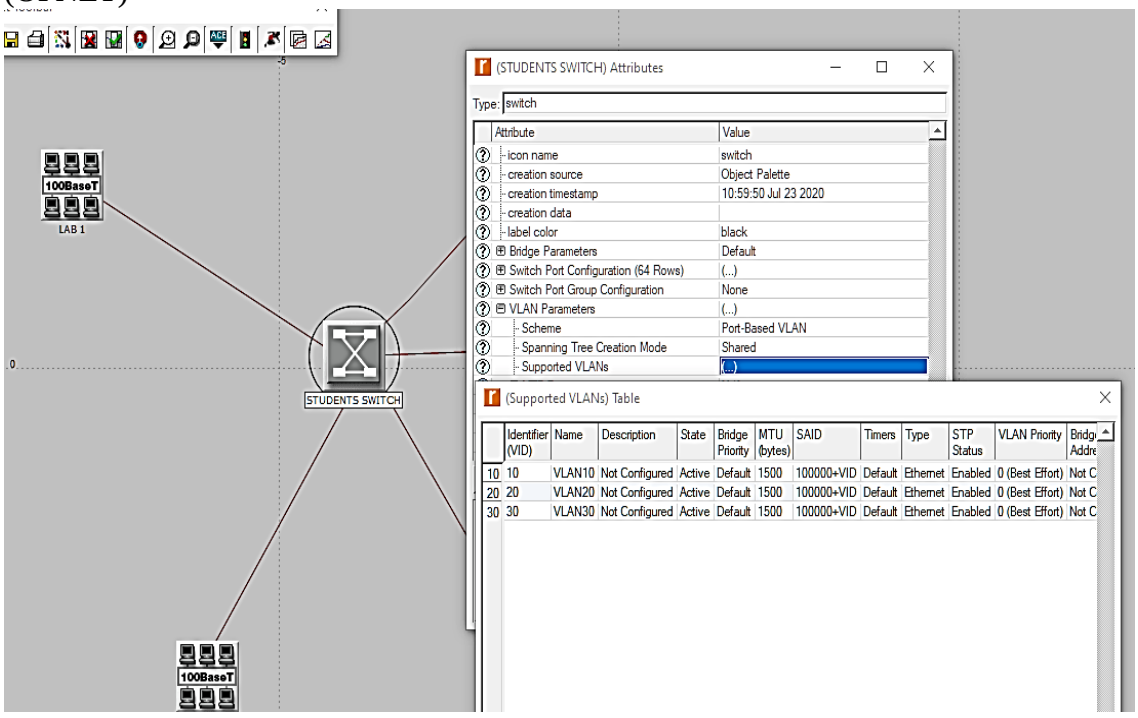

Figure 4. 33 Students LANs subnet VLAN configuration

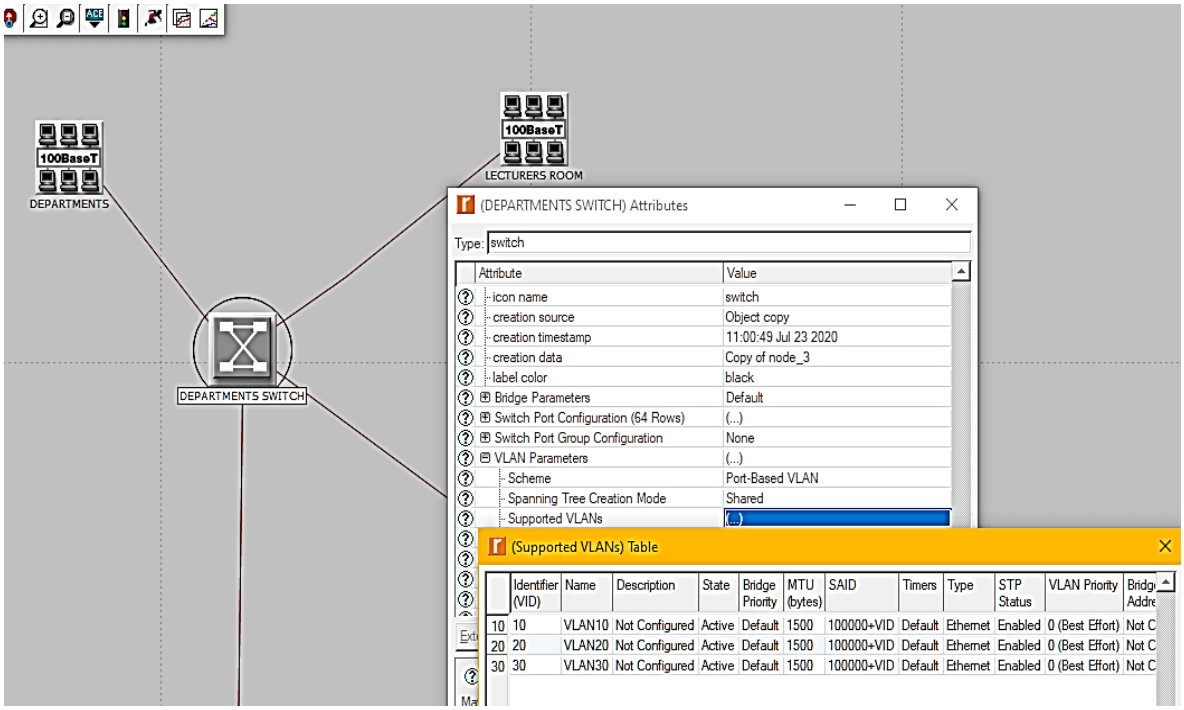

Figure 4. 34 Departments LANs subnet VLAN configuration

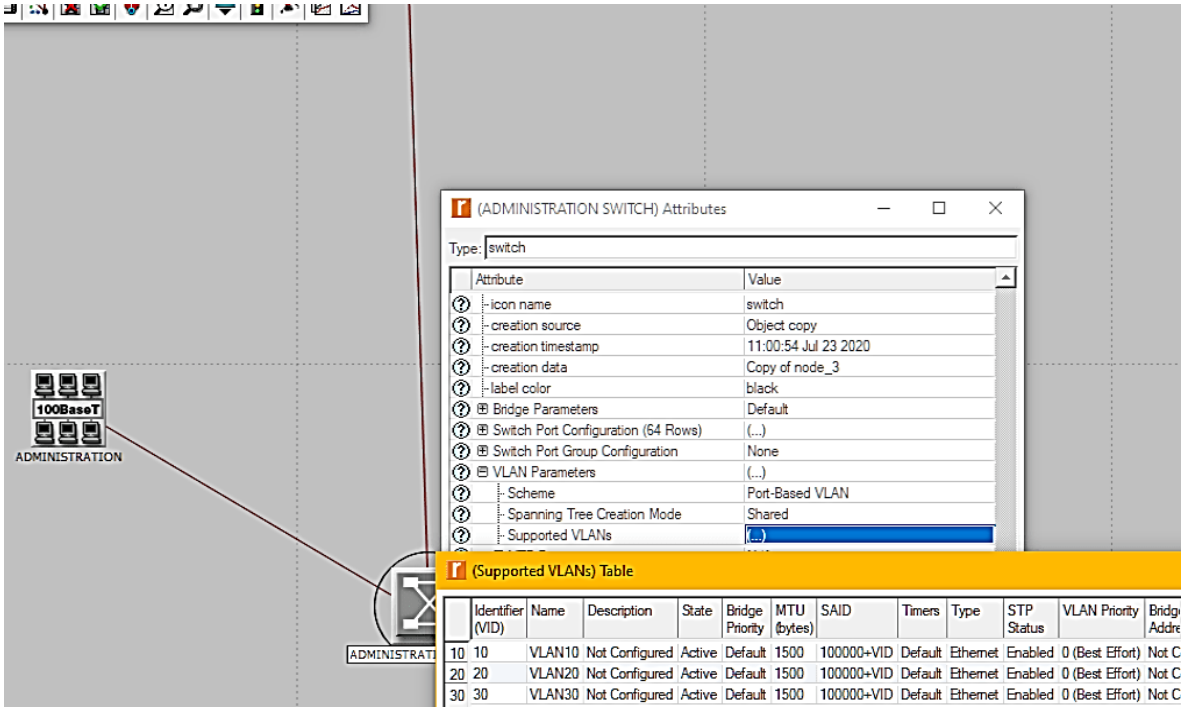

Figure 4. 35 administration LAN subnet VLAN configuration

Table 4. 22 VLANs group configuration.

subnets	Server	VLAN Name	VLAN ID
Students LANs	Web server	VLAN 10	10
Departments LANs	File server	VLAN 20	20
Administration LAN	Database server	VLAN 30	30

The table 4.23 shows the VLANs which are in the VLANs group configuration and show the virtual LANs on each LAN its name and ID in the reverbed modular.

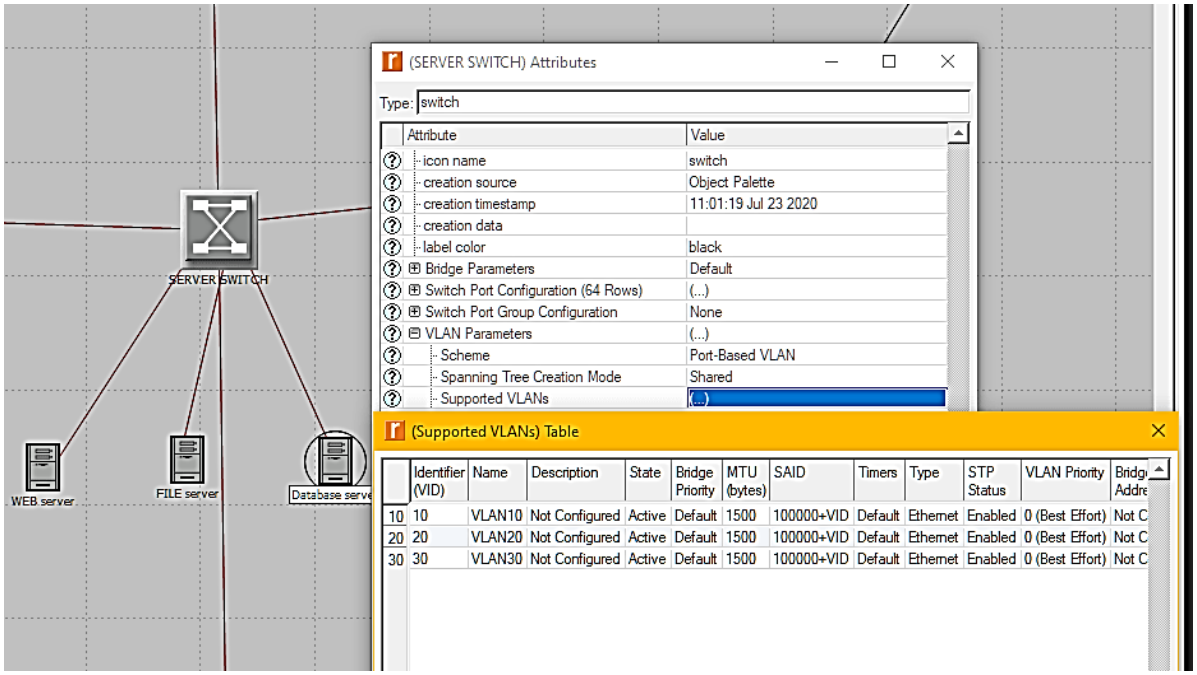

Figure 4. 36 Server switch subnet VLAN configuration

Figures 4.40 shows VLANs configuration in the entire network with in the server room they are 3 different servers (WEB, FILE and DATABASE) on different VLANs (VLAN 10, 20 and 30) respectively.

Table 4. 23 Server switch VLANs group configuration.

Server	VLAN Name	VLAN ID
Web server	VLAN 10	10
File server	VLAN 20	20
Database server	VLAN 30	30

4.7.2 Global statistics simulation results for ULB enhancement enterprise network performance with VLAN

The network was executed using VLAN to rectify the drawbacks for the existing enterprise network performance. The performance parameters that were considered in this research were average delay analysis, traffic sent and received, queuing delay for both (received and forwarded traffic) and application performance. The simulation results were obtained by using riverbed modeler academic Edition 17.5 (OPNET). VLAN scenario was used IEEE802.1Q VLAN protocol (VLAN). The results visualize the impact of VLAN protocol on traffic sent and received, queuing delay, response time and application performance.

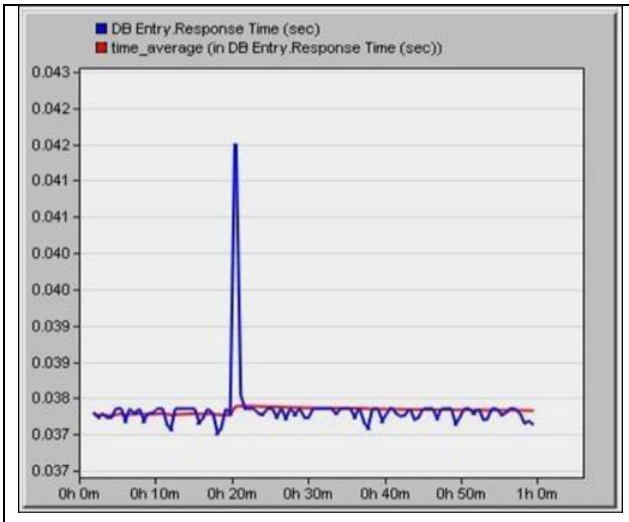

Figure 4. 37 Database Entry response time (sec)

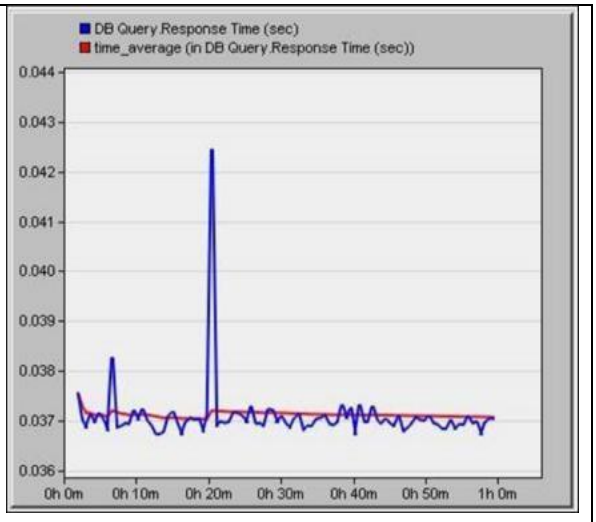

Figure 4. 38 Database Query response time (sec)

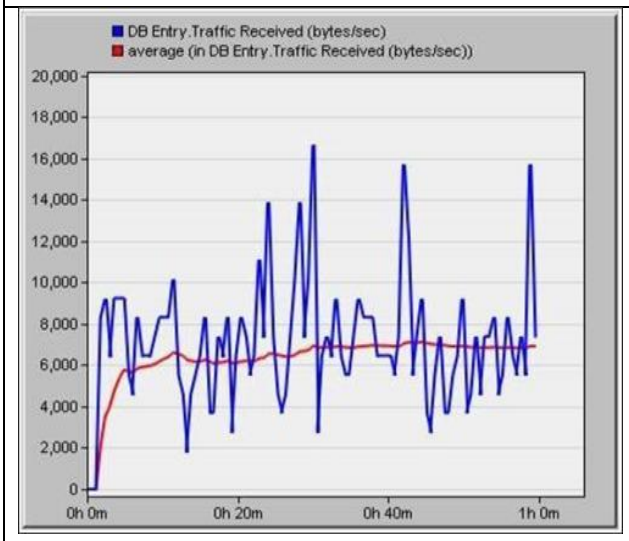

Figure 4. 39 Database Entry traffic received (bytes/sec)

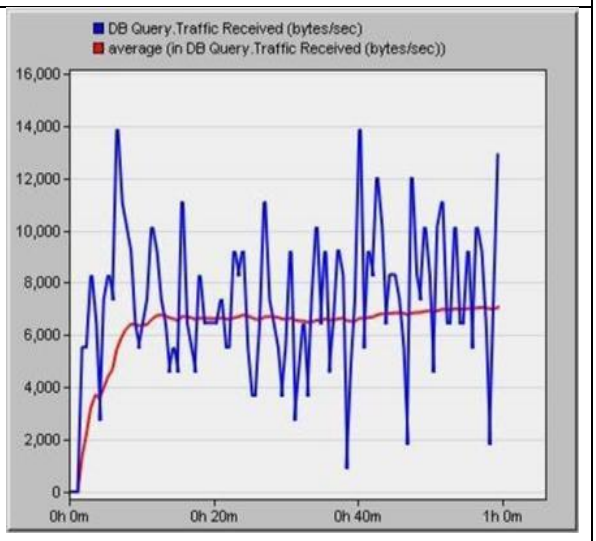

Figure 4. 40 DB Query traffic received (bytes/sec)

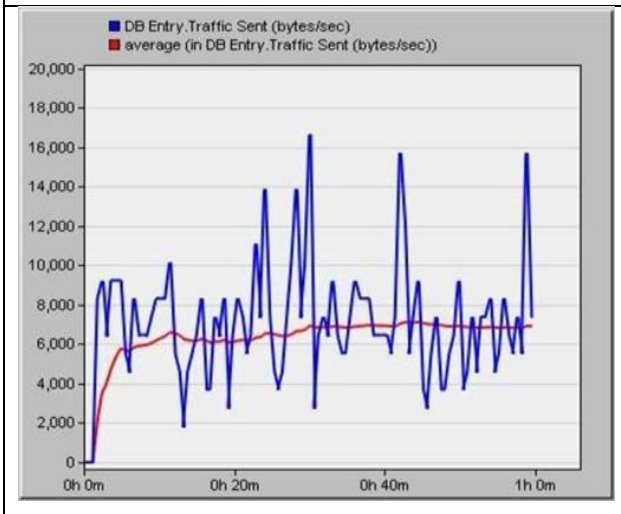

Figure 4. 41 Database Entry traffic sent (bytes/sec)

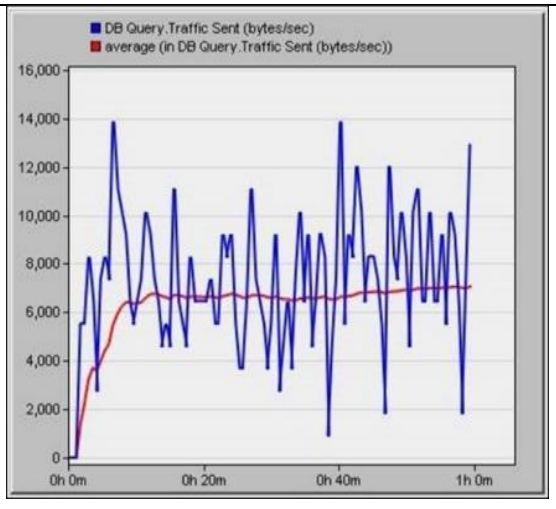

Figure 4. 42 Database Query traffic sent(bytes/sec)

The blue curves show how normally the simulation of the normal network and the red curves show the average time of the network.

Table 4. 24 Database Entry and Query global statistics data for VLAN

Global statistics	**Minimum**	**Maximum**	**Average time**
1. DB Entry response time (sec)	0.0375057372553	0.0415047340015	0.0378256845229
2. DB Query response time(sec)	0.0367247712423	0.0424468347645	0.0370716256787
3. DB Entry traffic sent(bytes/sec)	0.0	16,654.2222222	6,924.08888889
4. DB Query traffic sent(bytes/sec)	0.0	13,866.6666667	7,062.75555556
5. DB Entry traffic Received (bytes/sec)	0.0	16,654.2222222	6,924.08888889
6. DB Query traffic Received(bytes/sec)	0.0	13,866.6666667	7,062.75555556

The figures above are explained by this *Table 4.25* values in the global statistics simulation results, values show and measure clearly the network performance. it showed that traffic sent and received in database query and entry in the simulated figures above the table, they were the same for both received and sent traffic in Query and Entry data for minimum in simulation table for the above figures, but the response time for database entry and query were different the minimum and average for database Entry were higher than Query but the maximum for query is higher for the one of entry.

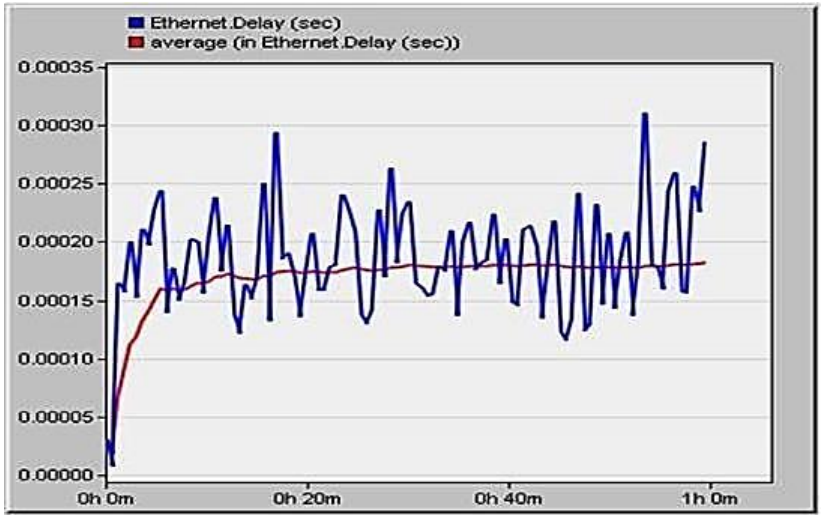

Figure 4. 43 Ethernet delay (sec)

Table 4. 25 Ethernet delay global statistics data for VLAN

Global statistics	**Minimum**	**Maximum**	**Average time**
7. Ethernet delay (sec)	7.95179204971E-006	0.00031087574389	0.000182337357046

This *Table 4.26* showed the global statistics simulation results of ULB enterprise network performance for all applications in the entire network. the red curve that shows average time delay and the blue curve that showed the ethernet delay which is measured in second.

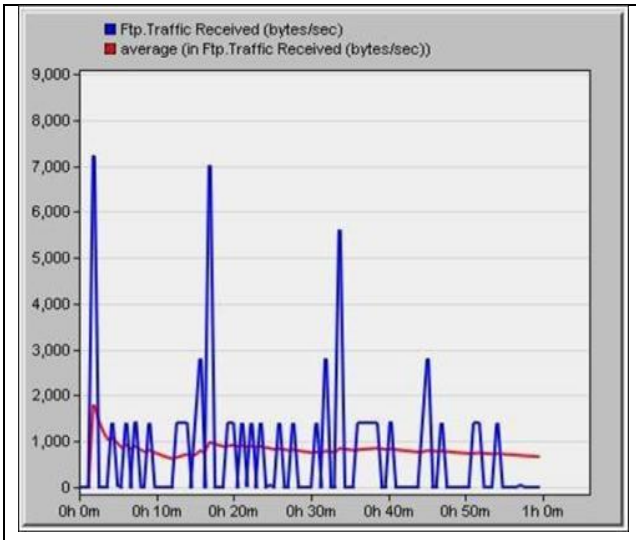

Figure 4. 44 FTP traffic received (bytes/sec)

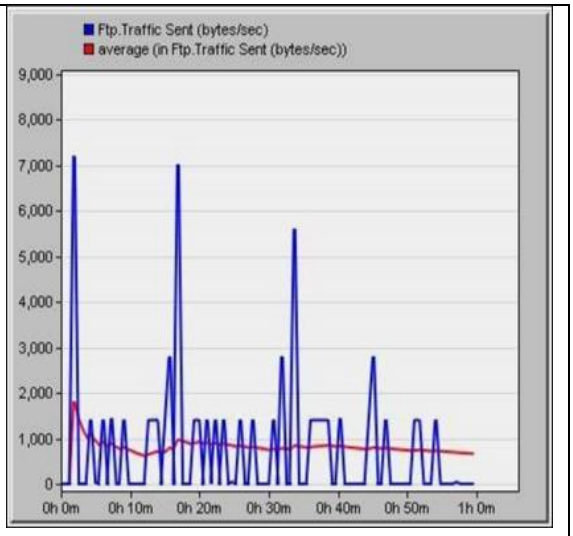

Figure 4. 45 FTP traffic sent (bytes/sec)

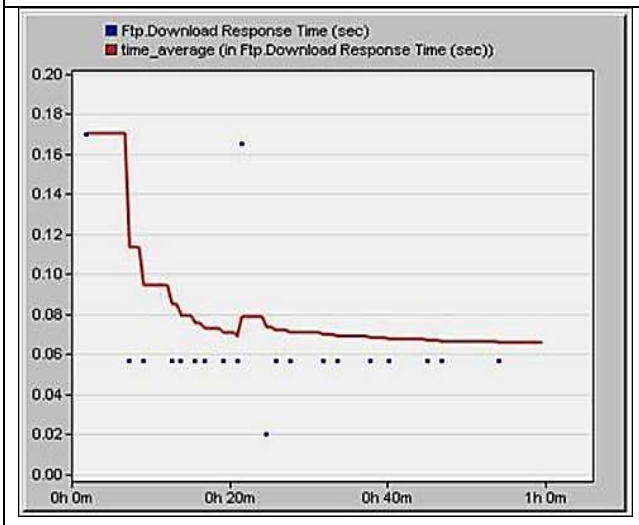

Figure 4. 46 FTP download response time (sec)

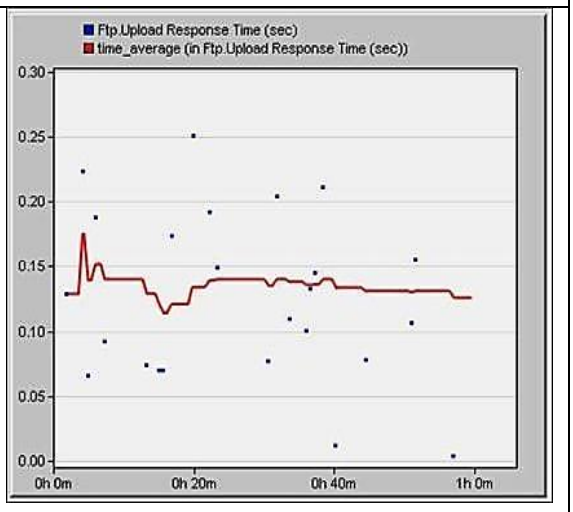

Figure 4. 47 FTP upload response time (sec)

Table 4. 26 FTP global statistics data for VLAN

Global statistics	**Minimum**	**Maximum**	**Average time**
8 FTP traffic received (bytes/sec)	0.0	7,225.55555556	664.082222222
9 FTP traffic sent (bytes/sec)	0.0	7,225.55555556	664.082222222
10. FTP download response time(sec)	0 .020595495768	0.170461625313	0.0659855610806
11. FTP upload response time(sec)	0.00416623202636	0.251496438916	0.125792937504

The *Table 4.27* presented the global simulation results for FTP traffic sent and received (bytes/ sec) showed the same results in the minimum, maximum and average. However, FTP upload response time (sec) took higher response time than FTP download response time. FTP application for upload and download response time in VLAN scenario presented in above figures were shown in blue curves for maximum and minimum but the average time is shown in red It is clearly seen that the VLAN scenario has a better performance in download than upload response time.

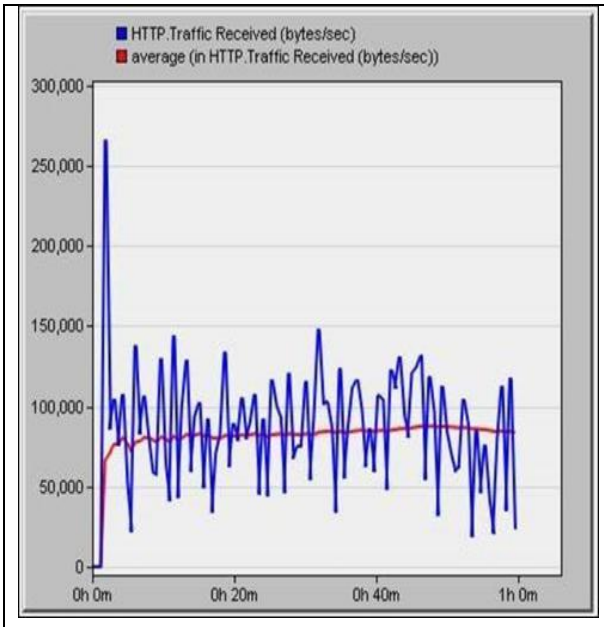

Figure 4. 48 HTTP traffic received (bytes/sec)

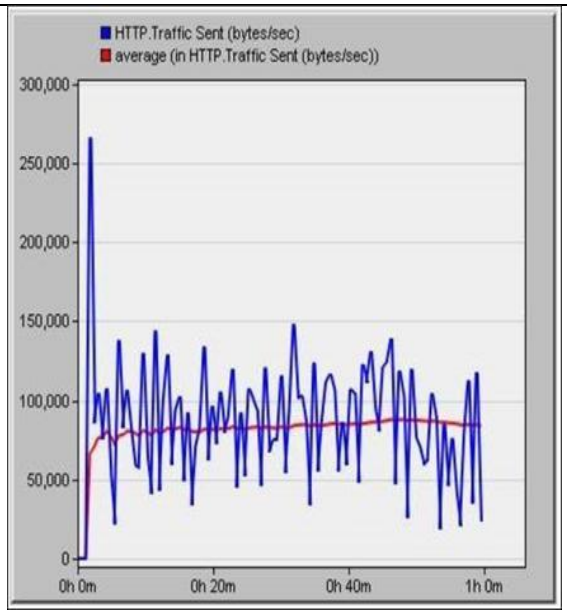

Figure 4. 49 HTTP traffic sent (bytes/sec)

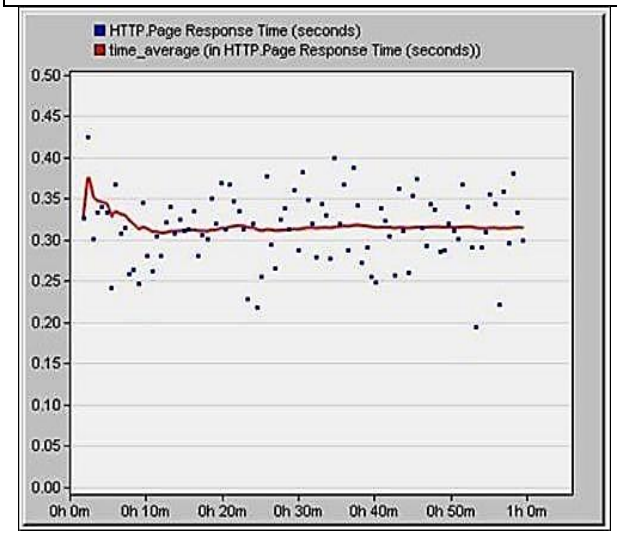

Figure 4. 50 HTTP page response time (sec)

Table 4. 27 HTTP global statistics data for VLAN

Global statistics	**Minimum**	**Maximum**	**Average time**
12. HTTP page response time(sec)	0.195251976255	0.42582517117	0.314844405202
13. HTTP traffic received (bytes/sec)	0.0	266,707.833333333	83,890.1316667
14. HTTP traffic sent (bytes/sec)	0.0	266,654.416666667	84,013.3969444

In this table with the figures above has shown the global statistics simulation results of the HTTP (hypertext transfer protocol) the traffic received and sent (bytes/sec) in HTTP had the

same statistic data, they were all started from zero for minimum and they had almost the same simulation results for maximum and average time global statistics data. page response time (sec) from minimum to maximum has taken almost times twice time of the maximum response time. The average was shown in red curves and maximum and minimum in blue curves.

4.7.3 Object statistics simulation results for ULB enhancement enterprise network performance with VLAN.

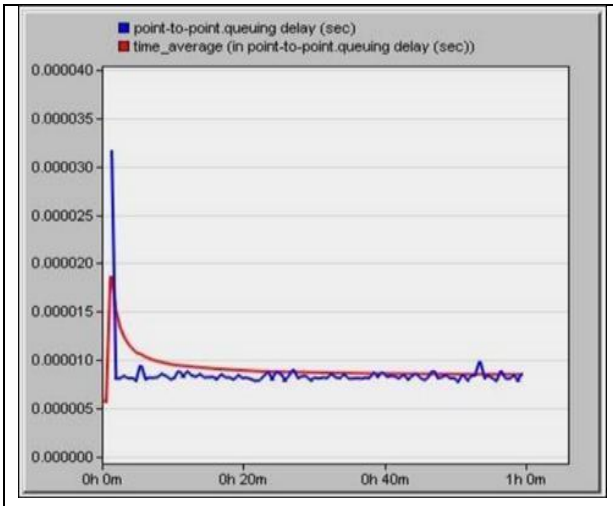

Figure 4. 51 Students queuing delay (sec)→

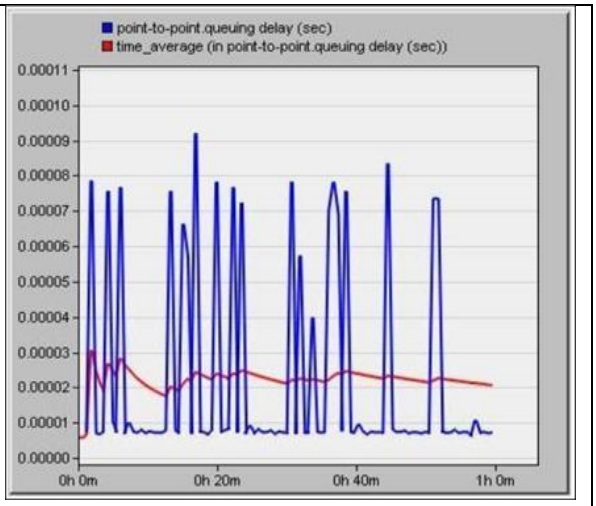

Figure 4. 52 Departments queuing delay (sec)→

Figure 4. 53 Administration queuing delay (sec)→

Table 4. 28 Queuing delay) → (forwarded data traffic) object statistics for VLAN

Object statistics	**Minimum**	**Maximum**	**Average time**
1. Students queuing delay (sec)→	5.76E-006	3.16622222224E-005	8.50739820216E-006
2. Departments queuing delay (sec)→	5.76000000003E-006	9.19251063888E-005	2.06049276179E-005
3. Administration queuing delay (sec)→	5.76000000003E-006	0.000107607032797	7.60456150558E-005

This *Table 4.29* has shown the forward data traffic for the object statistics data that minimum data statistics were having the same in queuing delay for the sent data and the maximum data statistics for administration had the highest time queuing delay, thus average was shown in red curves, maximum and minimum in the figures were shown in a blue curve. the departments queuing delay came the second for the higher number queuing delay and the last is students sent statistics data for queuing delay. but the average time object statistics data the students took much average time than the others. The administration had the second higher and the lowest was the administration queuing delay time and last was the departments which had lower queuing delay on the entire network.

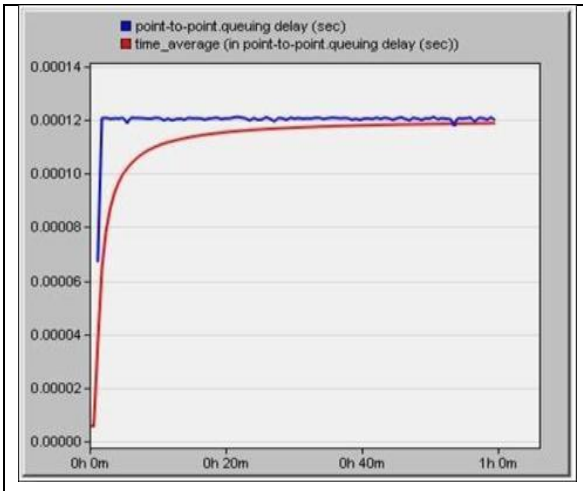

Figure 4. 54 Students queuing delay (sec)←

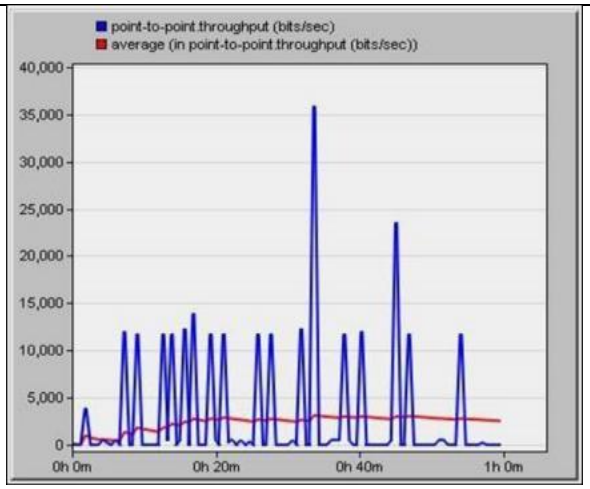

Figure 4. 55 Departments queuing delay (sec)←

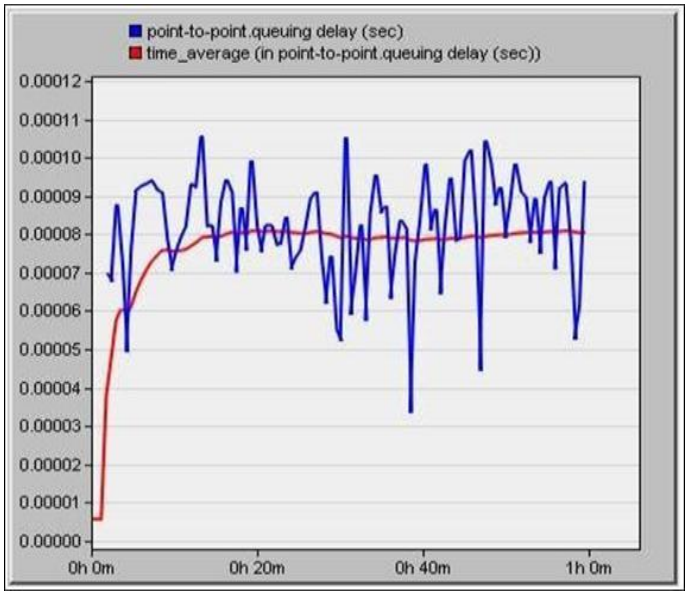

Figure 4. 56 Administration queuing delay (sec)←

Table 4. 29 Queuing delay ←(received data traffic) object statistics for VLAN(separate the)

Object statistics	**Minimum**	**Maximum**	**Average time**
4 Students queuing delay (sec)←	5.76000000003E-006	0.000121181277454	0.000118834903131
5 Departments queuing delay (sec)←	5.76000000003E-006	0.000111865263169	5.06611938299E-005
6 Administration queuing delay (sec)←	5.76000000003E-006	0.000105656774197	8.04933451836E-005

This *Table 4.7.3.2* has shown the received data traffic for the object statistics data

That minimum data statistics were having the same in queuing delay for the incoming data and the maximum data statistics for students queuing delay had the highest time, thus maximum and minimum in the figures were shown in a blue curves and average was shown in red curves the departments queuing delay came the second for the higher number queuing delay and the last is administration queuing delay for incoming or received statistics data. but the average time object statistics data the students took much average time than the others. The administration had the second higher and the lowest was the administration queuing delay time and last was the departments which had lower queuing delay on the entire network.

4.8 Comparison of Simulation results and measurement for both NO_VLAN and VLAN enterprise network performance.

This research provided two scenarios, the objective of these scenarios was to compare the performance of enterprise network (NO_VLAN) and Virtual Lan. The network was executed with two different scenarios NO_VLAN and VLAN. The performance parameters that were considered in this research were average delay analysis, traffic sent and received, queuing delay for both (received and forwarded traffic) and application performance. The simulation results were obtained by using riverbed modeler academic Edition 17.5 (OPNET). Both scenarios were using different data link layer protocol such as IEEE802.3 Ethernet LAN protocol (NO_VLAN) and IEEE802.1Q VLAN protocol (VLAN). The results visualize the impact of different protocol on traffic sent and received, queuing delay, response time and application performance.

It was obviously seen that there was different traffic sent and received of buildings between VLAN and NO_VLAN scenarios over all buildings A and B. VLAN scenario has lower traffics and queuing delay than NO_VLAN scenario because Virtual Lan scenario has separated a single large broadcasting domain into three broadcasting domains in order to reduce and control traffic sent and received of the network. Virtual local area network technology was used to alleviate vulnerability surface for hackers by reducing the traffic request to servers.

4.8.1 Global statistics simulation results for ULB enhancement enterprise network performance with both NO_VLAN and VLAN.

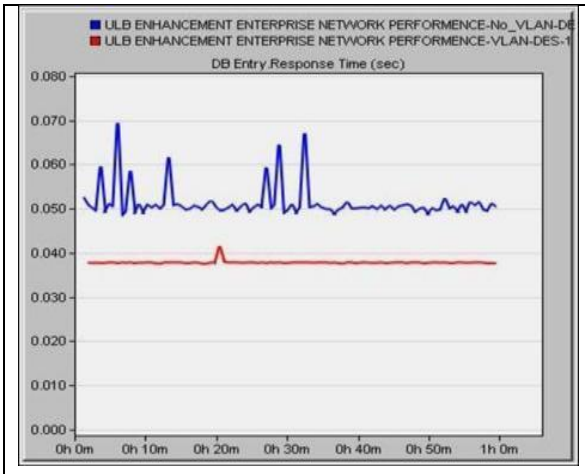

Figure 4. 57 Database Entry response time (sec)

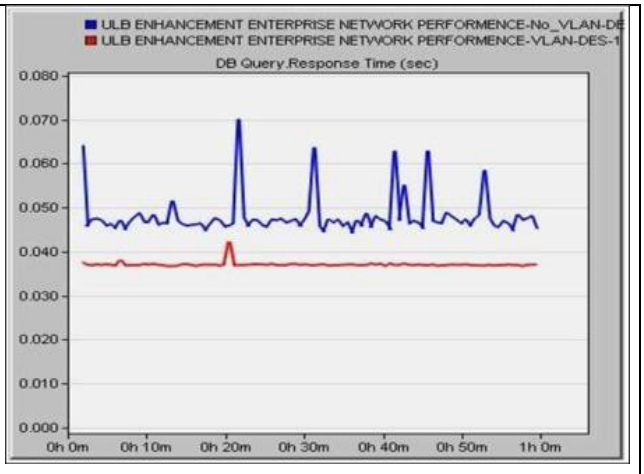

Figure 4. 58 Database Query response time (sec)

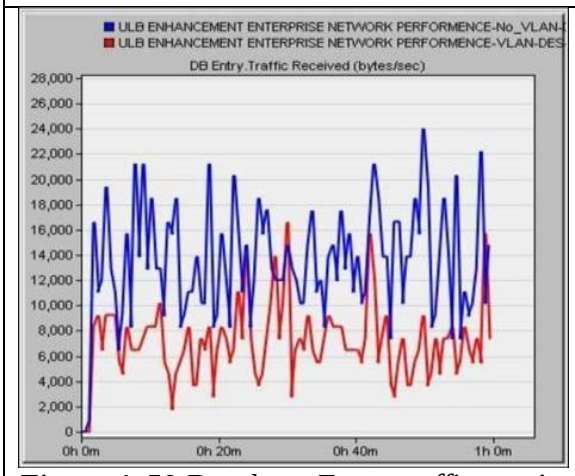

Figure 4. 59 Database Entry traffic received (bytes/sec)

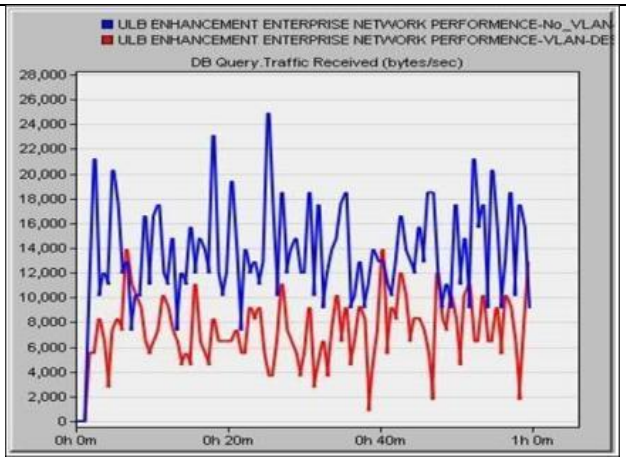

Figure 4. 60 Database Query traffic received (bytes/sec)

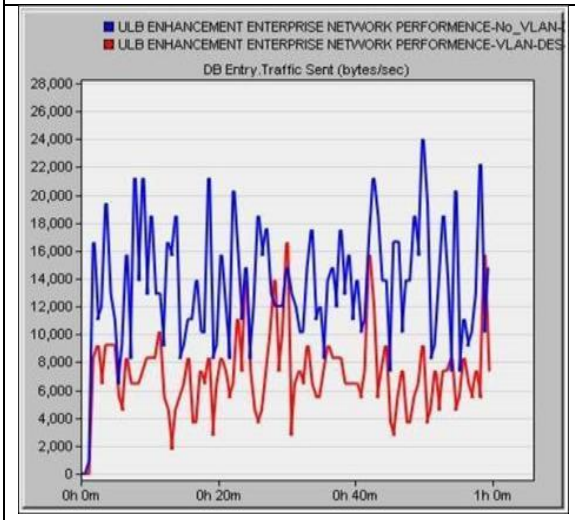

Figure 4. 61 Database Query traffic sent (bytes/sec)

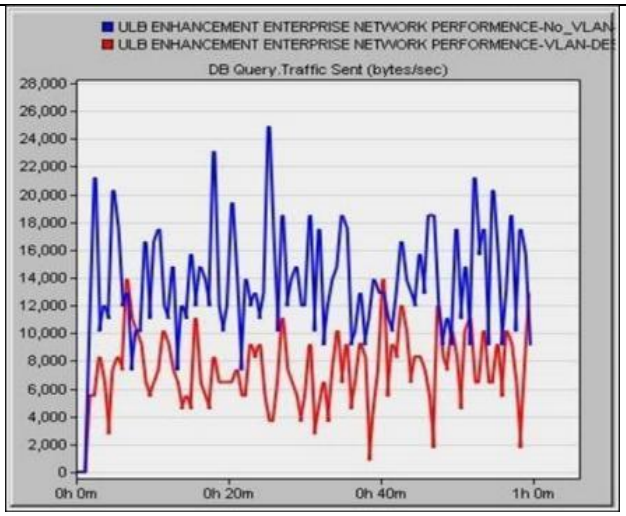

Figure 4. 62 Database Query traffic sent (bytes/sec)

Table 4. 30 Database Entry and Query for global statistics data

Global statistics	**Minimum**	**Maximum**	**Average time**
1.a. DB Entry response time (sec)VLAN b. DB Entry response time (sec) NO_VLAN	0.0375057372553 0.0485985062868	0.0415047340015 0.0694791734469	0.0378256845229 0.0511945834623
2. a. DB Query response time(sec) VLAN b. DB Query response time(sec)NO_VLAN	0.0367247712423 0.0444101892368	0.0424468347645 0.0701269191489	0.0370716256787 0.0479528663348
3. a. DB Entry traffic sent(bytes/sec) VLAN b. DB Entry traffic sent(bytes/sec) VLAN	0.0 0.0	16,654.2222222 24,035.5555556	6,924.08888889 13,164.0888889
4.a. DB Query traffic sent(bytes/sec) VLAN b. DB Query traffic sent(bytes/sec) No_VLAN	0.0 0.0	13,866.6666667 24,960	7,062.75555556 13,182.5777778
5. DB Entry traffic Received (bytes/sec) VLAN b. DB Entry traffic Received (bytes/sec) NO_VLAN	0.0 0.0	16,654.2222222 24,035.5555556	6,924.08888889 13,164.0888889
6.a. DB Query traffic Received(bytes/sec) VLAN b. DB Query traffic Received(bytes/sec) NO_VLAN	0.0 0.0	13,866.6666667 24,960	7,062.75555556 13,182.5777778

In the table 4.31 shows the simulation results of global statistics at ULB enterprise network for both scenarios VLAN and NO_VLAN, the simulation showed that traffic sent and received in database query and entry were the same started from zero in minimum global statistics but the response time for database entry and query were different, NO_VLAN had more traffic than VLAN in database entry and query response time and average time results were higher than database query response time, but maximum database query and entry for NO_VLAN had much traffic because the network had a single broadcast domain which slows

down the entire network, It is clearly showed that the VLAN scenario had a better performance in terms of sending and receiving traffic and response time.

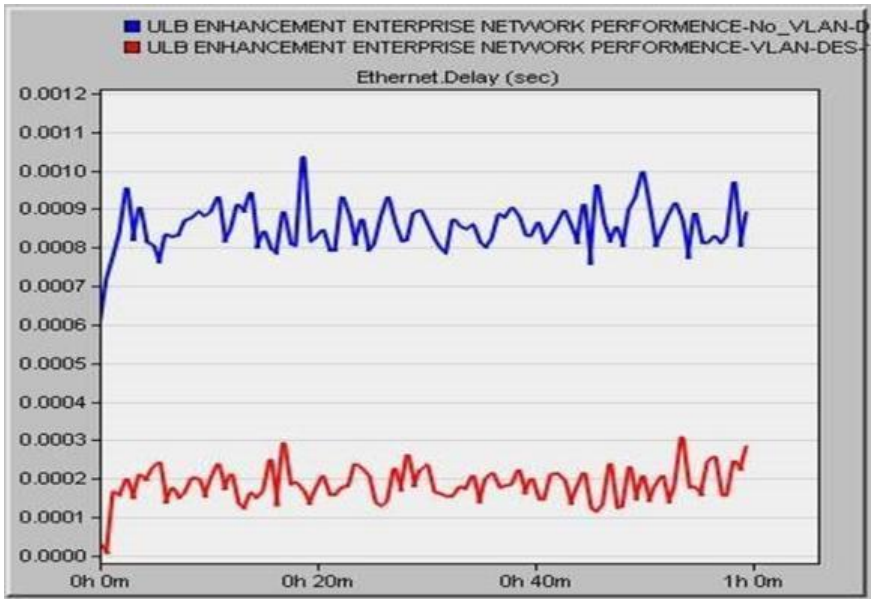

Figure 4. 63 Ethernet delay (sec)

Table 4. 31 Ethernet delay for global statistics data

Global statistics	**Minimum**	**Maximum**	**Average time**
7.a. Ethernet delay (sec) VLAN	7.95179204971E-006	0.00031087574389	0.000182337357046
b. Ethernet delay (sec) NO_VLAN	0.00060685468432	0.00103659364566	0.000850873310869

The table 4.32 showed the global statistics simulation results of ULB enterprise network performance for ethernet delay (sec) in both scenarios VLAN with red curve and NO_VLAN in blue. the NO_VLAN had much delay compared with VLAN. The red curve has lower delay which meant that VLAN had better performance due to segmentation of the single broadcast domain into three broadcast which reduced the time delay.

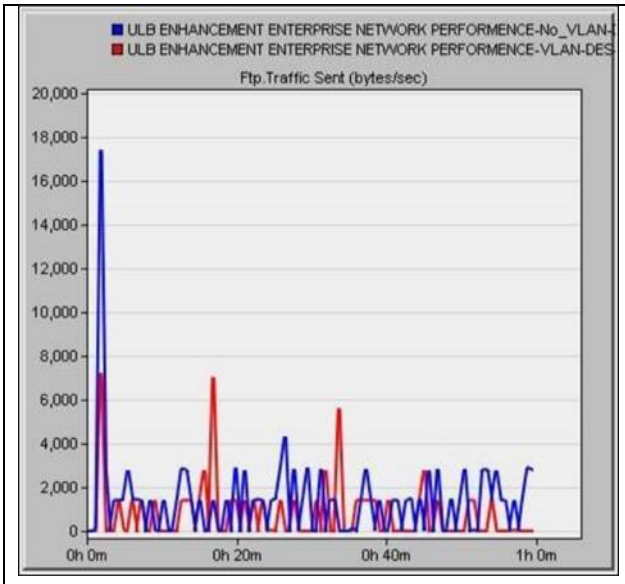

Figure 4. 64 FTP traffic sent (bytes/sec)

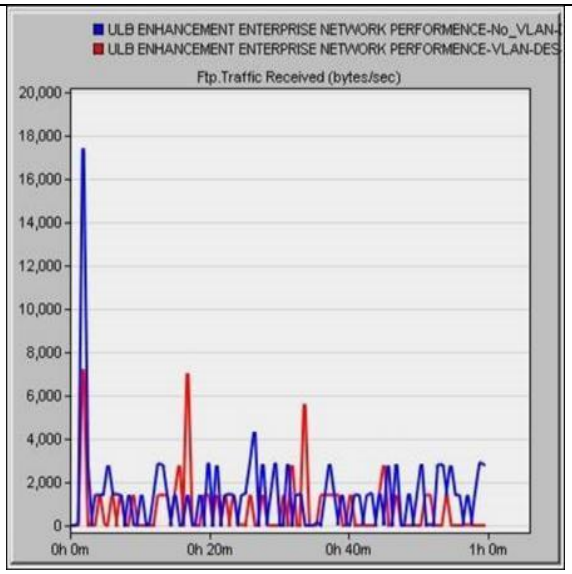

Figure 4. 65 FTP traffic received (bytes/sec)

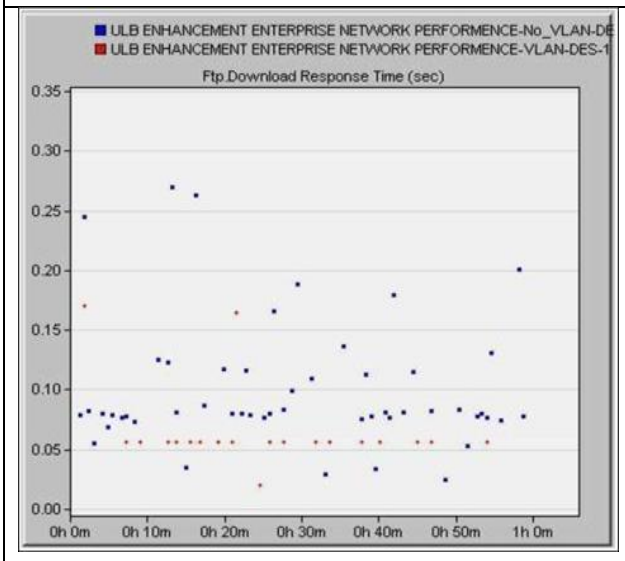

Figure 4. 66 FTP download response time (sec)

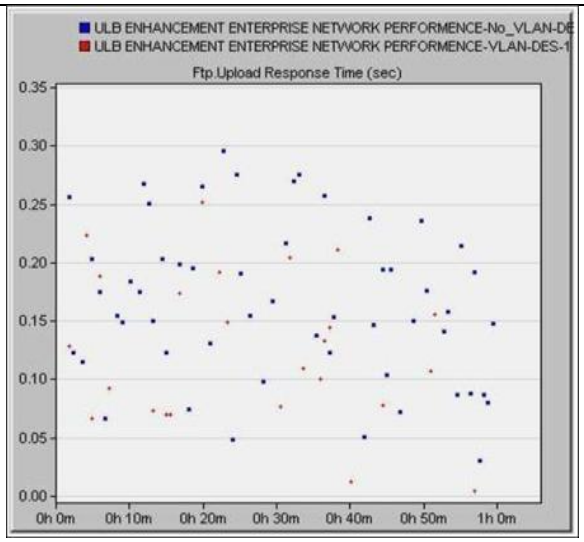

Figure 4. 67 FTP upload response time(sec)

The red curves show the simulation results for the network performance with NO_VLAN and the blue curves show the network performance with VLAN and the figures are well interpreted in the table 4.33

Table 4. 32 FTP for global statistics data

Global statistics	**Minimum**	**Maximum**	**Average time**
8 a. FTP traffic received (bytes/sec) VLAN	0.0	7,225.55555556	664.082222222
b. FTP traffic received (bytes/sec) No_VLAN	0.0	17,408.2222222	1,280.93777778
*9 a.*FTP traffic sent (bytes/sec) VLAN	0.0	7,225.55555556	664.082222222
b.FTP traffic sent (bytes/sec) VLAN	0.0	17,408.2222222	1,280.93777778
10.a. FTP download response time(sec) VLAN	0.020595495768	0.170461625313	0.0659855610806
b. FTP download response time(sec) NO_VLAN	0.0253783996459	0.270075329652	0.10090825247
11. FTP upload response time(sec)VLAN	0.0308728549885	0.251496438916	0.125792937504
b. FTP upload response time(sec) NO_VLAN	0.00416623202636	0.295512491191	0.165057092442

The simulation for FTP (File Transfer Protocol) application in both scenarios has shown application performance was evaluated with both VLAN and NO_VLAN scenarios. The time delay is the key performance indicator for upload and download in such application and also received and sent traffic showed the performance of the entire network.

Upload and download response time in both scenarios for FTP application are presented from the figures above in the table 4.33. the figures showed the global statistics data for the response Time and the sent and received traffic for both VLAN and with NO_VLAN for FTP application.

upload and download response time in both scenarios for FTP application are presented in figures above the VLAN scenario presented a lower traffic compared to NO_VLAN. It is clearly shown that the Virtual LAN scenario had a better performance in terms of upload and download response time and traffic sent and received (green and blue curves) compared with NO_VLAN scenario with heavy load FTP application. The difference between two scenarios

is becoming large during the simulation. As a result, VLAN technology considered as a best tool for heavy load applications and on single broadcast domain.

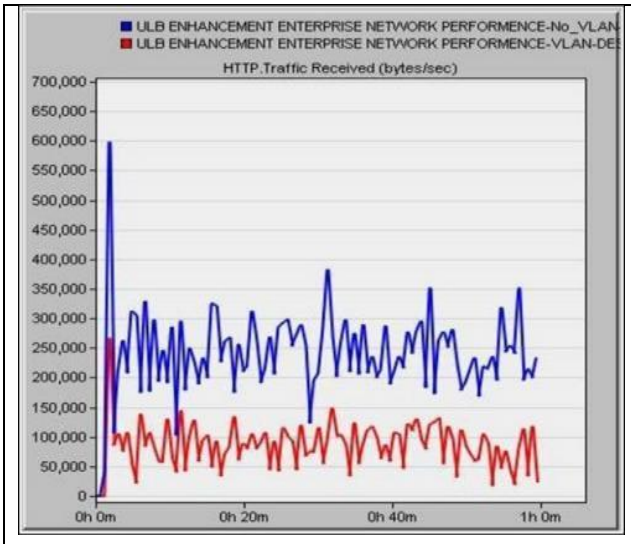

Figure 4. 68 HTTP traffic received(bytes/sec)

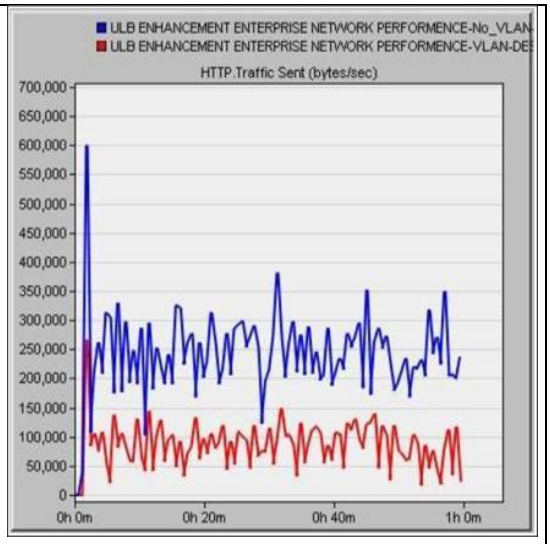

Figure 4. 69 HTTP traffic received(bytes/sec)

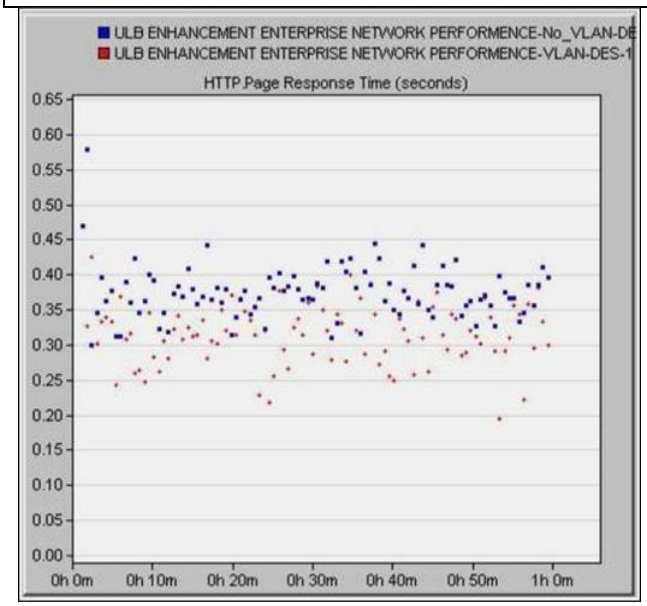

Figure 4. 70 HTTP page response time(sec)

The red curves show the network performance with NO_VLAN and the blue curves represent the network performance with VLAN.

Table 4. 33 HTTP for global statistics data

Global statistics	**Minimum**	**Maximum**	**Average time**
12.a. HTTP page response time(sec)VLAN *b.* HTTP page response time(sec)NO_VLAN	0.195251976255 0.299969619033	0.42582517117 0.578671187558	0.314844405202 0.374898135245
13. a. HTTP traffic received (bytes/sec) VLAN b. HTTP traffic received (bytes/sec) NO_VLAN	0.0 0.0	266,707.833333333 599,544.472222222	83,890.1316667 237,261.350555
14. a. HTTP traffic sent (bytes/sec) VLAN b. HTTP traffic sent (bytes/sec) VLAN	0.0 0.0	266,654.416666667 599,626.583333333	84,013.3969444 237,663.281944

In the figures 4.72,73 and 74 above the page response Time for both VLAN and with NO_VLAN for HTTP application, the graphs described that VLAN scenario has a lower page response time (red curve) and higher page response time (blue curve) with NO_VLAN scenario. In minimum global statistics for both scenarios in HTTP for received or sent traffic started at zero, however maximum and average time for global statistics data for HTTP, VLAN has lower traffic compared to NO_VLAN. The statistical values that are shown in minimum show where the simulation starts on the figures 4.72,73 and 74 and the maximin showed graphs on the top and average time.

In virtual LAN scenario for HTTP application had a better performance (red curve) compared to NO_VLAN with slightly higher performance (blue curve) in simulation.

4.8.2 Object statistics simulation results for ULB enhancement enterprise network performance with both NO_VLAN and VLAN

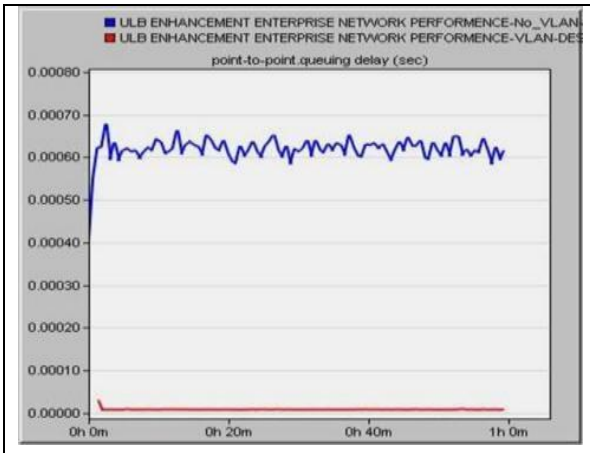

Figure 4. 71 Students queuing delay (sec)→

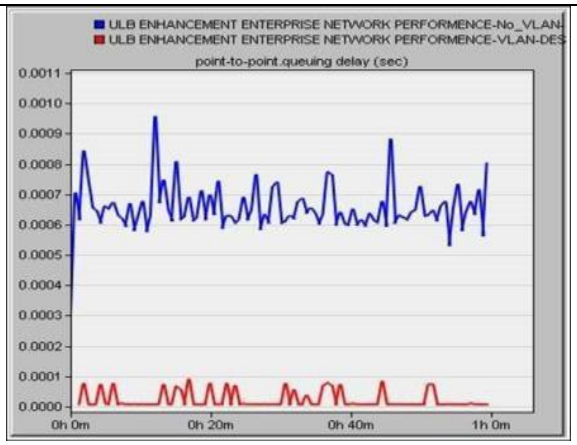

Figure 4. 72 Departments queuing delay (sec)→

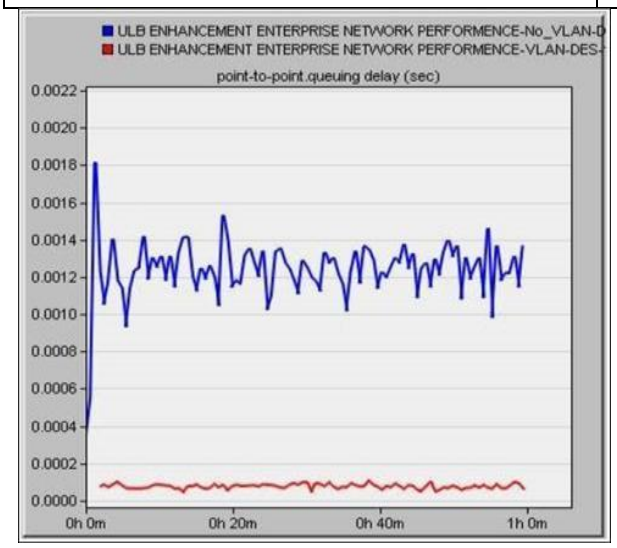

Figure 4. 73 Administration queuing delay (sec)→

Table 4.35 queuing delay →for forwarded traffic on both NO_VLAN and VLAN

Object statistics	**Minimum**	**Maximum**	**Average time**
1.a. Students queuing delay (sec)VLAN→ *b.* Students queuing delay (sec)NO_VLAN→	5.76E-006 0.000406039687747	3.16622222224E-005 0.000678808086534	8.50739820216E-006 0.000618223996928
2. Departments queuing delay (sec)VLAN→ b. Departments queuing delay (sec)NO_VLAN→	5.76000000003E-006 0.000307575550157	9.19251063888E-005 0.000957151456589	2.06049276179E-005 0.000652453623063
3. a. Administration queuing delay (sec)VLAN→ b. Administration queuing delay (sec)NO_VLAN→	5.76000000003E-006 0.00035489299559	0.000107607032797 0.00182003452083	7.60456150558E-005 0.00123289451776

The table 4.35 shows the statistical simulation values of the queuing delay for forwarded data for both VLAN and with NO_VLAN. This showed the performance for both. The campus network with VLAN showed better performance compared to the simulation network values with NO_VLAN. Moreover, the queuing delay is measured in second in table 4.35 which gives the values of the figures 4.75,76 and 77 which are for queuing delay for forwarded traffic on the campus network at ULB.

The students, departments and administration LANs queuing delay for forwarded traffic with NO_VLAN have higher traffic compare with the queuing delay with VLAN which means that VLAN has better performance over a network with NO_VLAN due to network segmentation, the values that are shown in the table are the simulation results got from the figures in the students, departments and administration LANs queuing delay for forwarded traffic at ULB. Therefore, the simulation results that were compared students' LANs on its own same on the departments' LANs and Administration' LANs on their own. queuing delay for received traffic minimum (at low), maximum (on the top) and average for both with NO_VLAN and with VLAN.

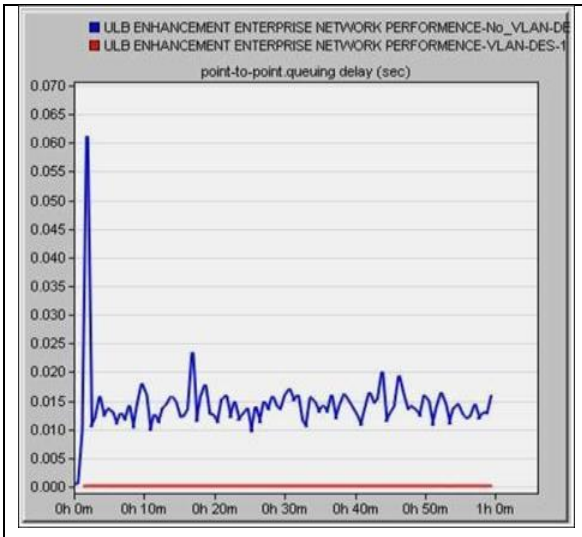

Figure 4. 74 Students queuing delay (sec)←

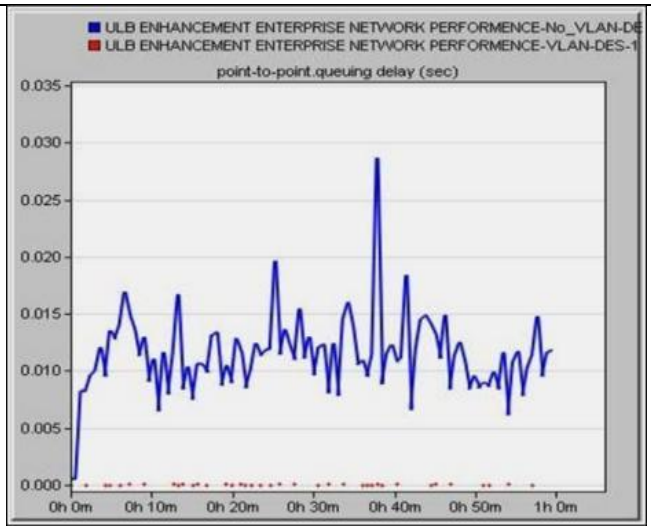

Figure 4. 75 Departments queuing delay (sec)←

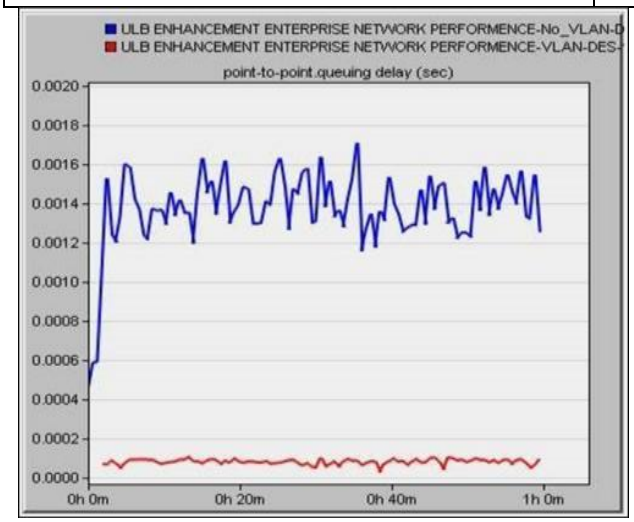

Figure 4. 76 Administration queuing delay (sec)←Table 4.36 queuing delay ←for received traffic on both NO_VLAN and VLAN

Object statistics	**Minimum**	**Maximum**	**Average time**
4 a. Students queuing delay (sec)VLAN←	5.76000000003E-006 0.000415082581562	0.000121181277454	0.000118834903131
b. Students queuing delay (sec)NO_VLAN←		0.0611603429427	0.0140558169895
5 a. Departments queuing delay (sec)VLAN←	5.76000000003E-006 0.000497926177654	0.000111865263169	5.06611938299E-005 0.0113112253334
b. Departments queuing delay (sec)NO_VLAN←		0.0286341656191	
6 a. Administration queuing delay (sec)VLAN←	5.76000000003E-006 0.000461776637034	0.000105656774197	8.04933451836E-005 0.0013686007295
b. Administration queuing delay (sec)NO_VLAN←		0.00170705905103	

The students, departments and administration LANs queuing delay for received traffic with NO_VLAN have higher traffic compare with the queuing delay with VLAN which means that VLAN has better performance over a network with NO_VLAN due to network segmentation, the values that are shown in the table are the simulation results got from the figures in the students, departments and administration LANs queuing delay for received traffic at ULB. Therefore, the simulation results that were compared students' LANs on its own same on the departments' LANs and Administration' LANs on their own. queuing delay for received traffic minimum (at low), maximum (on the top) and average for both with NO_VLAN and with VLAN. Moreover, the queuing delay is measured in second in table 4.36 which gives the values of the figures which are for queuing delay for received traffic on the campus network at ULB.

A. Traffic forwarded

Traffic forwarded was measured in second which were composed by traffic sources across all subnetworks.

In the figures shown above the traffic sent for switch traffic forward of buildings in both VLAN and NO_VLAN scenarios.

B. Traffic received

The traffic received of buildings A and B for both VLAN and NO_VLAN scenarios is measured in second as shown in table (4, 5 and 6) across all subnetworks and all scenario.

From the above graphs in Figures in building A and B for both scenarios, it concluded that the virtual local area network curve (red curve) has lower values of forwarded and received traffic than NO_VLAN curve (blue curve) across all LANs in two buildings. Nevertheless, the traffic received and forwarded in switches have highly reduced with Virtual LAN technology compared with NO_VLAN because the network broadcasting domain was segmented into three logical networks (three Virtual LANs) in order to distribute users. Therefore, Virtual LAN scenario divides the total users by three; Virtual local area network alleviates the risk of broadcasting storm by reducing attacking surface. Under VLAN scenario, students are prohibited to access on administration LAN except their college departments Therefore, VLAN can reduce the congestion level in networks with more bandwidth utilization.

The end-to-end queuing delay of all frames by nodes is measured in second for both building A to building B link (students to server switch, departments to server switch and Administration to server switch) link as shown in figures above new enterprise network with

Virtual LAN implementation. The presented results in Figures above for object statistics of all subnets to server switch link indicate that VLAN scenario has less queuing delay than NO_VLAN scenario because of VLAN has less traffic flow over the time of simulation. However, the minimum value of queuing delay is approximately same for links building A-B to server switch for forwarded and received traffic in VLAN case, but in both cases are different for maximum queuing delay and VLAN has lower traffic compared with NO_VLAN.

It is clearly shown that in both tables of queuing delay for forwarded and received traffic that the VLAN technology minimized the queuing delay for links between switches as expected because of VLAN scenario has less forwarded and received traffic. Virtual local area network works to distribute users over several logical broadcasting domains, the performance was much improved compared to NO_VLAN scenario. The data statistics analysis of all subnets (Administration, Departments and Students) to server switch link in tables 4.35 and 4.36 for both scenarios shows that VLAN scenario has lower queuing delay compared NO_VLAN scenario. This means that VLAN is an advantageous tool to reduce the queuing delay of communicating users for fast transmission.

Table 4.37 Summary of data analysis and interpretation of results

Objectives	**Research design**	**Source of data**	**Data analysis tools**	**Outcome**
Objective one	**Quantitative**	Primary Data, 2020	questionnaire	Majority of End users were unsatisfied with the enterprise network performance
Objective two	**Qualitative**	Primary Data, 2020	Structured interview guide	ajor drawback was unsegmented network in the existing enterprise network performance at ULB
Objective three	**Quantitative**	Primary Data, 2020	Riverbed Modeler Academic Edition 17.5 (OPNET)	enterprise network components with NO_VLAN was implemented into OPNET, simulated and measured with the global statistics
Objective four	**Quantitative**	Primary Data, 2020	Riverbed Modeler Academic Edition 17.5 (OPNET)	Duplication of existing enterprise network into the OPNET simulation with VLAN implementation and measured the statistics
Objective five	**Quantitative**	Primary Data, 2020	Riverbed Modeler Academic Edition 17.5 (OPNET)	The results were Compared both scenarios with NO_VLAN and with VLAN. The measured network performance showed that Virtual LAN scenario had better performance compared to NO_VLAN scenario.

CHAPTER FIVE

DISCUSSIONS, CONCLUSION AND RECOMMENDANTIONS

5.1 Introduction

The chapter presents the conclusions and recommendations about the study basing on the findings presented in chapter four above. The conclusions and recommendations were presented according to the study objectives below. Furthermore, limitations and areas for further research were also presented under this chapter.

5.2. Discussion

Modern organizations are facing problems related to poor network s design which affects services in many fields that leading the responsible categories to interested in improving network local area performance by measuring the quality of services for the network (Walaa , Norah, & Badryah , 2016).

According to ubuntuNet alliance (2017) Burundi has left the country's research and education struggling to afford high speed and affordable internet connectivity.

The findings on the data that was corrected using questionnaire showed that majority were unsatisfied with the network performance without VLAN due to issues in a poorly designed network that have many issues that impacted the network performance. Issues typically found like unbound failure domains large broadcast domains, large amount of unknown MAC address unicast traffic, difficulty management and support and security vulnerability.

The structured interview was the responded by a network and system administrators at ULB the data corrected from these respondents, the purpose was to get the big picture of the network infrastructure (components) that is built the campus network at ULB.

The drawbacks were identified due to the components that were in the existing network. The major drawbacks identified; the existing enterprise network was not segmented it was a single large broadcast domain.

This means that if a user broadcasts information on enterprise network or local area network, every user will receive the broadcast. The drawback of this technique is for the incoming data routers usually take more time to process compared a switch or to a bridge. More

significantly, formation of broadcast domains depends on the physical connection of the devices in the network.

The existing enterprise network (without VLAN) The simulation results were measured and obtained by using riverbed modeler academic Edition 17.5 (OPNET).

The components that were built into the network at ULB and the components were implemented into OPNET.

A virtual local area network is a switched network that is logically segmented based on features such as service requirement, workgroup and protocol or application requirement rather than on a physical or geographical proximity (Isiaka & Akeem , 2015). With the implementation of VLAN, geographically dispersed workstations, servers and other peripheral devices used by a particular workgroup can be put on the same VLAN and communicate as if they are physically on the same location in the network (Alimi, Mufutau, & Ebinowen, 2015).

The existing enterprise network was rectified with the implementation of virtual local area network using riverbed modeler academic Edition 17.5 (OPNET). VLAN technology alleviated end to end delay and improved the network performance due to network segmentation VLAN can be used for security reasons (Kiravuo, Sarela, & Manner, 2013). It can also improve bandwidth utilization, power, speed and security. VLANs can break the large physical LANs into small logical LANs to address the high traffic problem (Dhurgham , 2018).

According to Dhurgham VLANs have higher flexibility than LAN to organize the devices/users into groups with logical LAN, they can communicate each other as if they are on the same wired LAN dependent on the logical connection rather than physical one.

VLANs was characterized by defining broadcast domains that span multiple LANs segments, improve segmentation, flexibility, and security. VLANs segmentation is not bound by the physical location of the user and VLANs are added to ethernet frames via 802.1Q headers.

The findings showed that riverbed modeler simulator compared both scenario with and without VLAN, the results shown in the graphs that Virtual LAN scenario performed better because of the segmentation of single large broadcasting domain into three broadcasting domains in order to reduce and control traffic sent and received on the network and without VLAN scenario had much traffic compared to VLAN scenario.

The findings of this study recommend that ULB and other universities should implement virtual local area network to enhance enterprise network performance, since VLAN can significantly improve the network performance as well enforce network security.

The study recommended that ULB and other universities should implement virtual local area network to improve enterprise network performance, since Virtual LAN can significantly enhance the network performance as well enforce network security.

5.3 Conclusion

5.3.1 Investigation of End User satisfaction of enterprise network performance at ULB

Findings showed that on the level of agreement regarding the level of end user satisfaction, respondents said they were unsatisfied with enterprise network performance (NO_VLAN).

The most frequently occurring value in data set about the level of end user satisfaction was one which represented the respondents who were very unsatisfied with the enterprise network performance at Université Lumière de Bujumbura that was the mode of the end user satisfaction with the existing network performance without virtual local area network. The median had a value of two which is in the middle of the ordered data set in 2^{nd} position which is unsatisfied with the enterprise network. The central tendency of ordinal data set is where mostly values lie mode and median are most commonly used to measure the central tendency of ordinal data for measuring the level of end user satisfaction with the existing enterprise network performance using virtual local area network implementation. The bar chart represented the percentage of how respondents responded on the questionnaire that were given out to find out the level of end user satisfaction of the existing enterprise network performance.

The most occurring value was for the respondents who were very unsatisfied with network performance and was easily seen in the bar graph because it was the value with the highest bar.

The respondents were 219 who responded the questionnaire of the objective, about of the level of end user satisfaction on the enterprise network performance. The data that was collected at Université Lumière de Bujumbura, the majority of respondents were not satisfied with the network, which was very important to implement virtual local area network in the existing network.

Hence, there is a need of analyzing the existing enterprise network performance with virtual local area network implementation.

5.2.2 Drawbacks identification of existing enterprise network at ULB.

The structured interview were the questions responded by a network administrator and system administrator at ULB about the enterprise network structure and all components that are build the ULB network. In structured interview guide, the internet service provider was Burundi Backbone System (BBS) company which is providing the bandwidth of 6Mbps but for two universities the main campus and the branch on this bandwidth the main campus is using 3 Mbps and the branch is also using 3 Mbps and the network topology was a star topology. the network was slow during peak time due to unsegmented local area network. the end users who use more bandwidth than others were students. RIP was routing protocol which was being used; additionally, there was no user access policies enforced which was allowing user to download or upload at any time,

Therefore, causing lack of bandwidth to user. The entire enterprise network at ULB is built by firewall using cat 6 cable to a 4500 router as gateway and connected to an IP cloud using fiber cable (ppp_28K); there is four switches in two buildings; each switch had 48 ports. in first building there was three labs connected to one switch with cat 6 cable which connects to server switch and the second building there is three switches, one switch connects two LANs one cat 6 goes to all school departments LAN and another goes to lecturer's room LAN and there is administration LAN on other switch which was connected to server switch. There was a server room in second building which had a 48-ports switch connected with three servers was connected to the firewall talked above those servers were web, file and database .in both buildings each switch there was wireless LAN ethernet router that is connected to it except server switch.

According to the system administrator at ULB, he gave out his point of view of the network performance. the network has been slow in the morning because of the highest number of students are accessing the network we have three servers are on web, file and database servers their capacities are one Tb, two Tb and two Tb respectively there were core i7 and there is also cache memory server but no proxy server.

5.2.3 Measurement of the existing enterprise network performance (NO_VLAN)

The first scenario was designed to visualize an enterprise network (NO_VLAN). However, in two buildings there were four main switching devices, students switch for Students Lan with three Labs in building A and in building B there were departments switch for departments Lan and lecturers room Lan, administration switch for Administration Lan and the servers switch in server room that also connect all three switches (students, departments and administration LANs) and connected to the gateway and Ip cloud. The simulation results were obtained by using riverbed modeler academic Edition 17.5 (OPNET). In this scenario; The statistical simulation results on the existing enterprise network by using traffic sent and received, queuing delay (received and forwarded traffic), average time analysis, response time, download and upload response time and application were the key performance indicators in global and object statistics; the network was measured using minimum, average and maximum statistical data on the graph which represent the network performance.

There was single broadcasting domain network only. Therefore, users were allowed to access to confidential servers and share all resources. All nodes were communicating each other because there were no restrictions. Therefore, there were much traffic requests on servers due to single broadcast domain.

5.2.4 Drawbacks rectification by Implementation of virtual local area network in the existing enterprise network.

The simulation results were obtained by using riverbed modeler academic Edition 17.5 (OPNET). The simulation results visualize the impact of different protocol on traffic sent and received, queuing delay (received and forwarded traffic), average time analysis, response time, download and upload response time and application performance.

New enterprise network (VLAN) scenario was a duplication of the existing enterprise network (NO_VLAN) which was implemented into it a configuration of Virtual LAN, it was segmented with three logical group of users, which were found in two buildings (A and B). These users are logically segregated for many reasons by using different VLANs such as students, department and administration LANs.

Virtual LAN technology was employed in switches for segmenting the single broadcast domain However, primary driver behind Virtual LAN is to reduce the traffic congestion on the large local area network. Virtual LANs broke the large physical LANs into small logical

LANs to address the high traffic problem. the main purpose of VLAN technology was to increase the network efficiency by reducing the broadcasting domain size. Thus, the host at different VLANs cannot directly communicate each other. Moreover, VLAN was used for security reasons. Virtual LANs have higher flexibility than LAN to organize the devices/users into groups with logical local area network.

5.2.5 Objective Five: To simulate and compare the new (VLAN) and existing (NO_VLAN) enterprise network performance.

The simulation and comparison between new (VLAN) and existing (NO_VLAN) enterprise network performance using riverbed modeler academic Edition 17.5 (OPNET) was important on this research to know the different network performance for both scenarios. Virtual LAN scenario had lower traffic sent and received, queuing delay, download and upload response time than NO_VLAN scenario because Virtual LAN scenario has segmented a single large broadcasting domain into three broadcasting domains in order to reduce and control traffic sent and received of the network. Virtual LAN technology can be used to mitigate vulnerability surface for hackers by reducing the traffic request to servers. On the other side, VLAN can achieve the power reduction in switches by reducing the required power to forward and receiving unnecessary traffic. This has affected the bandwidth utilization. VLAN (red curve) had lower values of traffic sent and received than NO_VLAN curve (blue curve) across all nodes/LANs in two buildings. However, the traffic sent and received had reduced with VLAN technology compared with NO_VLAN because the network broadcasting domain has divided into three logical networks in order to distribute users. NO_VLAN scenario has higher traffic than VLAN scenario due to a single broadcast domain but virtual LAN works better by segmenting a single large network domain into three broadcast domains to achieve higher utilization of bandwidth with less traffic level.

Thus, Virtual LAN scenario divides the total users by three; Virtual LAN mitigates the risk of broadcasting storm by reducing attacking surface. Under VLAN scenario, Students LAN were prohibited to access administration LAN. Therefore, Virtual local area network can reduce the congestion level in networks with more bandwidth utilization.

Queuing delay, Traffic sent and received, response time and average time for links and applications were the key performance indicators. Virtual LAN was proved that it has limited access to the confidential server database by controlling traffic and achieving better security and having less level of congestion. The comparison results for both existing (NO_VLAN) and new (VLAN) enterprise network performance gave a clear picture about selection of

virtual local area network technique for heavy load applications gives a significant result for the performance of the network. This research aimed to enhance existing enterprise network performance by implementing Virtual LAN technology, which have many advantages in terms of power, delay and bandwidth utilization. it helps also for cost effectiveness because it does not require more additional component to improve the performance.

5.4 Recommendations

The researcher recommends:

1) This study recommends that ULB and other universities should implement virtual local area network to enhance enterprise network performance, since Virtual LAN can segment a single large broadcasting domain into multiple broadcasting domains in order to reduce and control traffic sent and received of the network. Virtual LAN technology can also be used to mitigate vulnerability surface for hackers by reducing the traffic request to servers.
2) Policy makers in charge of information technology should put in place a network usage policy on all institutions which will provide detailed guidelines on network user access. The policy must be used to determine and govern issues such as:
    i. to use the local area network for the core purpose for which it was put in place.
    ii. to monitor the internet usage patterns and enforce the appropriate sanctions where necessary.
    iii. To protect all university computers which connected to the local area network from virus and spam attacks.
3) The network administration of different universities should emphasize the importance and necessity of configuring VLAN on the existing enterprise network (NO_VLAN) so that students and university staff could be accessing a good network with quality which will help them to perform well their daily campus activities like learning, teaching online courses, research and sharing information.
4) it is also recommended that the network administrators should make adequate use of the proxy server, application server and also managing bandwidth utilization with squid Guard.

5.5 Limitations

Complexity in mobilizing students since they were sitting in exams during the collection of data. Meeting class by class helped to achieved so. Translating the questionnaires into French was also a challenge the researcher faced. On the same note, a research gap was the main challenge of this study since no such study has been done at ULB. Referring to other studies helped to conduct accurately this research. Without forgetting the impact of Covid-19 on transport which made the travel to Burundi complex due to the measures taken by ministry of transport of Uganda.

5.6 Contributions

1. The findings of this research showed that enterprise network with virtual local area networks implementation provide enhanced network security on the LAN at ULB. In virtual LAN network environment, with multiple broadcast domains segregated from a single large broadcast domain, network administrators have control over each port and user. A malicious user can no longer just plug their workstation into any switch port and sniff the network traffic using a packet sniffer. The network administrator controls each port and whatever resources it is allowed to use. Virtual local area networks help to restrict sensitive traffic originating from an enterprise department within itself.

2. The findings showed that broadcasts Control are required for the normal function of a network performance. Many protocols and applications depend on broadcast communication to function properly. A layer 2 switched network is in a single broadcast domain and the broadcast can reach the network segments which are so far where a particular broadcast has no scope and consume available network bandwidth. A layer 3 device (typically a router) is used to segment broadcast domain.

If we segment a large local area network to smaller virtual local area network, we can reduce broadcast traffic as each broadcast will be sent on to the relevant virtual local area network only.

3. Segmenting a large local area network at ULB to smaller virtual area networks is cheaper than creating a routed network with routers because normally routers costlier than switches.

4. Virtual local area networks have physical layer transparency on the physical topology and medium over which the network is connected.

5.7 Area for further studies

As supported on the finding of this study, methods used from the literature and conclusions drawn,

the researcher found it suitable to suggest the following survey to be prepared. They will help for

further and appropriate to minimize unnecessary network traffic and make available more bandwidth to the entire university community.

1. Future research will be done on using parallel firewalls to improve the network performance

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APPENDICES

Appendix A : Transmitter Letter

ENHANCEMENT OF ENTEPRISE NETWORK PERFORMANCE THROUGH VIRTUAL LOCAL AREA NETWORK IMPLEMENTATION: CASE STUDY UNIVERSITÉ LUMIÈRE DE BUJUMBURA, KININDO, BUJUMBURA, BURUNDI

ORIGINALITY REPORT

16%	14%	0%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.iasj.net Internet Source	5%
2	www.ijsr.net Internet Source	2%
3	pdfs.semanticscholar.org Internet Source	2%
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6	Submitted to Polytechnic of Namibia Student Paper	2%
7	researchoutput.csu.edu.au Internet Source	2%

APPENDICES

Appendix B : Consent Letter

Questionnaire for students and staff at Université Lumière de Bujumbura

As Master student at Kampala International University, I am conducting research on Enhancement of Enterprise Network Performance Through Virtual Local Area Network Performance Implementation. With regards I request you to spare a few minutes to fill in the questionnaire as diligently as possible. The information in this questionnaire is strictly confidential and will not be used for any other purpose than for this research. Your assistance in facilitating this research will be highly appreciated.

Thanks.

PART A

Please tick as appropriate.

1. Gender

   Male [ ]

   Female [ ]

2. What is your end user role?

   1. Student [ ]
   2. Faculty staff [ ]
   3. Administration staff [ ]

3. How long have you been at Université Lumière de Bujumbura?

   1. 1-6 Months [ ]
   2. 6-12 Months [ ]
   3. 1-3 Years [ ]
   4. Over 3 Years [ ]

PART B: GENERAL INFORMATION.

4. How do you feel with the university network speed?

1. very unsatisfied [ ] 2. Unsatisfied [ ] 3. Neutral [ ] 4. Satisfied [ ] 5. Very Satisfied [ ]

5. Are you contented with the availability of the campus network?

1. Never [ ] 2. Rarely [ ] 3. Sometimes [ ] 4. Often [ ] 5. Always [ ]

6. What do you do with the campus network (download or Upload)?

1. Download [ ] 2. Upload [ ] 3. Both [ ] 4. Chat [ ] 5. Search [ ] All [ ]

7. What is the most likely website do you often access to?

1. Social Medias [ ] 2. Torrent [ ] 3. Commercial [ ] 4. Streaming websites [ ] 5.Research [ ] 6. All [ ]

8. At what time do you use campus network?

1. Morning time [ ] 2. Afternoon time [ ] 3. evening time [ ]

9. What devices do you use for accessing the campus network?

1. Phone [ ] 2. Tablet [ ] 3. Laptop [ ] 4. Desktop [ ]

10. What type of campus network do you use to access internet?

1. Wireless [ ] 2. Wired [ ] 3.Both [ ]

Structured interview guide ICT technical team at Université Lumière de Bujumbura

As Master student at Kampala International University, I am conducting research on Enhancement of Enterprise Network Performance Through Virtual Local Area Network Performance Implementation. With regards I request you to spare a few minutes to respond on these questions as diligently as possible. The information in this structured interview is strictly confidential and will not be used for any other purpose than for this research. Your assistance in facilitating this research will be highly appreciated.

Thanks in advance.

PART A

Network administrator

Please tick as appropriate.

1. Gender

   Male [ ]

   Female [ ]

2. How long have you been at Université Lumière de Bujumbura?

   1. 1-6 Months [ ]

   2. 6-12 Months [ ]

   3. 1-3 Years [ ]

   4. Over 3 Years [ ]

PART B: GENERAL INFORMATION.

1. What is your internet service provider?

   _____

   _____

   _____

2. What is your network topology?

   _____

   _____

   _____

3. What are the network components that built the entire Local area network?

   _____

   _____

   _____

4. What is the size of the uplink and downlink (bandwidth size)?

_____

___

_____

___

_____

___

5. What is the experience of peak time (when everyone is on the network)?

_____

___

_____

___

_____

___

6. How is your network traffic segmentation from different types of end users?

_____

___

_____

___

_____

___

7. Do you have the graphs of the end users who use more bandwidth than others?

_____

___

_____

___

_____

___

8. Which routing protocol do you use?

_____

_____

_____

_____

9. Did you implement any access policy?

_____

_____

_____

Web administrator, database administrator, email administrator, system administrator

Please tick as appropriate.

1. Gender

   Male [ ]

   Female [ ]

2. What is your role?
   1. Web administrator [ ]
   2. Database administrator [ ]
   3. Email administrator [ ]
   4. System administrator [ ]
3. How long have you been here?

   1. 1-6 Months [ ]

   2. 6-12 Months [ ]

   3. 1-3 Years [ ]

   4. Over 3 Years [ ]
4. What is the network usage perception?

   _____

   _____

   _____

5. Which servers do you use and what are their capacities (processing and storage size)?

   _____

   _____

   _____

6. Do you have cache server?

   _____

   _____

   _____

7. Do you have proxy server?

Appendix B : BUDGET

Number	Items	Quantity	Unit Cost	Sub Total
1	Ream of Paper	1	12,000	12,000
3	Data	8GB	30,000	30,000
4	Transport		32,000	32,000
5	MacBook pro 2012	i5 8GB Ram 500GB hard disk	1,200,000	1,200,000
7	Charger	1	100,000	100,000
	TOTAL of all items			**1,374,000 Ugx**