UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

An Analysis of a campus LAN infrastructure: Case study for Kimathi University College

By

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Submitted in partial fulfilment of the requirements of the Master of Science in Computer Science

Declaration

This project as presented in this report, is my original work and has not been presented for any other University Award.

Signed: ....

Date: ....75/11/2012..

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P58/72972/2009

The project has been submitted as part fulfilment of requirements for the Masters of Science in Computer Science of the University of Nairobi with my approval as the University supervisor.

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To the fellow Msc. Computer Science students who were involved in testing the system and to everyone who contributed to the success of this project,

ABSTRACT

The revolution in computer networking technology today demands for high bandwidth, short response time, reliable network, guaranteed application services and optimum LAN traffic flow. Organizations require optimum network performance to support their business operations and changing customer needs. Therefore, analysis of network performance is very important to maintain and improve network efficiency from time to time.

The project set out to analyze network structure and design of Kimathi University College of Technology (KUCT) in relation to gauging some various aspects of network performance that included database response times in various locations of the university, critical university applications like smart card usage and the high bandwidth research lab that ought to have optimum and exciting browsing experience due to the very nature of their existence.

Various network designs were simulated *vis-à-vis* the existing network designs and the results were compared. The construction of the networks is based on aggregate information gathered from some selected production networks and is a representation of the status of our campus networks.

The results have been used for recommendations of the KUCT future network design if the optimal performance need to be attained. The results of the final simulations shows a clear difference of the current design and what is desired for the network perpetuation.

The load balancing has been enhanced by utilising normal distribution that populates EIGRP interfaces that achieves less response time in the database application and significant reduction of WAN link utilization due to utilization of firewall policy. This further reduces application responses of FTP and HTTP which are the parameters under scope.

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LIST OF ACRONYMS

ATM - Asynchronous Transfer Mode

DUAL - Diffusing update algorithm

EIGRP- Enhanced Interior Gateway Routing Protocol

FSM - Finite State Machine

FTP - File Transfer Protocol

HTTP- Hyper Text Transfer Protocol

ICT Center - Information and Communication Technology Centre

ID -Identity

IEEE - Institute of Electrical and Electronics Engineers

IGRP- Interior Gateway Routing Protocol

IP - Internet Protocol

KUCT- Kimathi University College of Technology

LAN- Local Area Network

NS-2 - Network Simulator 2

OPNET- Optimized Network Engineering Tool

PC - Personal Computer

QOS - Quality Of Service

SCSI - Small Computer System Interface

VOIP - Voice Over Internet Protocol

WAN- Wide Area Network

WAPS- Wide Area Protection System

CHAPTER ONE: INTRODUCTION

1.0 Project Background

The revolution in computer networking technology today demands for high bandwidth, short response time, reliable network, guaranteed application services and optimum LAN traffic flow. Organizations require optimum network performance to support their business operations and changing customer needs. Therefore, analysis of network performance is very important to maintain and improve network efficiency from time to time.

The Information and Communication Technology Centre (ICT Centre) for Kimathi University College was officially established on October 1, 2009 as a decision of the Management Meeting. The overall responsibilities of ICT Centre are that of coordination of ICT functionality within the functional departments of KUCT. Appreciating the importance of ICT, The management of Kimathi University College of Technology (KUCT) commissioned a fiber backbone infrastructure that interconnects different departments within the University main Campus. The installation also includes supply, installation and configuration of Cisco Layer 3 switches to segment different departments within the campus.

In few years' time the number of computer, laptop and smart phones users in KUCT will be increased as each employee gets their own desktop computer or laptop. Besides that, application systems in KUCT will be added or upgraded to support organization's business policy and user requirements. Therefore, network performance of the organization must be in good condition in order to provide appropriate quality of service (QOS) and to satisfy demanding users. In that light it is imperative to study & analyse the infrastructure with a view of gauging its efficiency, bottlenecks and make further suggestions for future improvement.

In this research a simulation tool was employed to model the network as a real world "what-if" problem. Information regarding business issues and technical requirements was gathered first to ease analysis of existing network infrastructure in KUCT. The current applications, hosts, topology, network designs and number of workstations was documented and tested using network simulation. Performance assessment gained from simulation was used as bench marking to improve network efficiency of the organization using appropriate suggestions. Suggestions to improve network efficiency was developed in prototype design and tested using network simulator. Lastly, both existing network design and suggested network design were compared based on network characteristics, advantages and disadvantages of the network designs. In this project, network performance of KUCT was analysed using OPNET IT Guru Academic Edition Version 9.1.A.

nalysis of network performance in KUCT was focussed more on bandwidth utilization, delay nd packet loss rate. Distribution of critical resources and segment workload was considered ecause unreasonable network resources allocation led to poor network performance.

.2 Problem Statement

he network growth is eminent since Kimathi University College is bound to grow to a fully-edged university in future. It is set to be a technological university. Performance contract from e office of the prime minister requires the university to raise the automation level from the urrent 40% to 60% this financial year. In light of that, the network infrastructure will form the asis on which this anticipated growth will be handled.

he need to study & analyze the current network is made clear because of the following reasons:

1. Gauging the current efficiency of the backbone network infrastructure.
2. The need to increase internet availability through enhanced load balancing
3. The need to make recommendations for future growth so as to make decisions from an informed point of view.

.3 Objectives of the Project

- To exploit an existing network simulation tool and the network infrastructure to develop a model that illustrates how the network parameters (response time and load balancing) can be optimized.
- To determine if the average utilization of the WAN link can be reduced by configuring firewall.
- To determine if the response time (FTP and HTTP) can be enhanced through load balancing.

.4 Scope

his project focused on Kimathi University college of Technology (KUCT). Specifically on ocal Area Network (LAN) connections in KUCT. All suggestions to improve network fficiency dependent on cost and physical limitations exist in the organization. The network mulation will be developed using OPNET IT Guru Academic Edition Version 9.1.A in Vindows 7 Premium operating system.

.5 Project Significance

nalysis of network performance in Kimathi University college of Technology (KUCT) will oduce network documentation that can be used as reference by the organization to implement new features in existing network. This documentation includes analysis of technical information and business policy that affects network infrastructure.

This project provides insight on existing network performance in KUCT. The network performance was simulated based on information gathered from the organization. Assessment of network performance will focus on bandwidth utilization, delay, packet loss rate, distribution of critical resources and segment workload. These results will be then used to identify problems and weaknesses of the existing network. Next, new network design that can produce better network performance and solve the problems will be proposed and tested in network simulator.

Based on network simulation results, ways to improve network efficiency in KUCT was discussed. Existing network characteristics and proposed network characteristics was compared and justified for better understanding.

This project also provided the chance to improve network efficiency in KUCT. This definitely benefited users and customers of KUCT because with better network performance users can perform well their tasks and provide better service to customers. IT officers of the organization also gained more knowledge about network analysis and design for optimum network performance.

Furthermore, using OPNET IT GURU simulation software saves cost and provides opportunity to correct mistakes that can be made when designing new network for the organization.

1.6 The Output

The outputs from this project were requirement analysis tables that provided information about applications, hosts, and user requirements. Besides that, diagrams of network architecture, topology model, physical and logical design for existing and proposed network were produced.

Besides that, network simulation was generated using OPNET IT Guru Academic Edition Version 9.1.A based on information gathered from the organization. These network simulations provided values that were used to generate graphs. Based on the values and graphs bandwidth utilization, delay and packet loss rate were analyzed.

1.7 Conclusion

As a conclusion, the project analyzed network performance in Kimathi University college of Technology (KUCT). A number of achievements were realized. Among them were well redesigned network with similar response time for all users, high bandwidth research lab was also redesigned in simulation using load balancing and reduced WAN link utilization thus having good FTP download and Web response time. The proposed design was tested in simulation and compared with existing network characteristics. Main outputs of this project were network simulations, graphs, network designs and network flow diagrams.

The rest of this document/report is organised as follows; chapter 2 is a survey of the current literature in view of identifying the gaps thereof, chapter 3 is the methodology applied in this research, chapter 4 deals with simulations and experiments, chapter 5 highlights results and findings while chapter 6 & 7 entails the suggested network and conclusions & further work respectively.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

Network performance analysis is very important in every organization to ensure that business requirements and technical goals of the organization are fulfilled. Organizations are adding users, applications, additional sites, and external network connections at a rapid rate. Thus, network performance of the organizations must be in good state to operate well and to support the customer needs.

Network performance of Kimathi University college of Technology (KUCT) was analyzed using network simulation. [Abeysundara and Kamal, 2009], the three most commonly used performance measures are information throughput, channel utilization, and (various forms of) delay. Information throughput can be defined as the total number of information bits transmitted per unit time. Few of important parameters which will be focused on to assess network performance are as follows:

2.1.1 Load Balancing

The comparative investigation of three wide area protection System (WAPS) architectures, i.e. centralized, distributed and networked environment, revealed that networked structure is considered to be best due to its fast response time in terms of lesser delay or transfer time. The architecture and communication network of WAPS was investigated to utilize global information instead of local information to achieve better performance. The load on the network server increases with increase in the user activity. An increased number of users increase the network load and degrades the performance. An effort was made to improve the performance by load balancing. Various probabilistic methods to study network performance [Nobert and Joan, 2009] had been proposed during the research. The significance of using discrete-event simulation, as a methodology to confront network design and fine-tuning its parameters was also highlighted. Another major problem exists in the form of network congestion. To overcome the problem of congestion, Fiber Distributed Data Interface and Asynchronous Transfer Mode type high-performance networks along with the bucket congestion control mechanism were modeled and simulated by [Alborz and Keyvani, 2004]. The effect of variation in attributes like traffic load on the performance metrics like end-to-end delay and throughput was analyzed. The increase in traffic load effects the network performance In a simulation done by [Zubairi and Mike, 2008] on SUNY Fredonia Campus Network Simulation , a network model with switched Ethernet subnets and Gigabit Ethernet backbone under typical load conditions and also for time-sensitive applications such as video streaming over was modeled and simulated. The simulations were carried out to study the impact of increase in traffic load on the performance metrics like delays was analyzed. The type of routing technique used in the network is an important consideration to study the network performance. Three technologies – Internet protocol (IP), Asynchronous Transfer Mode (ATM) and Multiprotocol Label Switching (MPLS) were compared in terms of their routing capability by [Hazif and Golam, 2008]. Different performance metrics like end-to-end Delay, throughput, Channel Utilization, FTP download response time and normalized delivered traffic were analyzed using network simulator. The results indicated that ATM and MPLS outperform IP (without modification) in terms of delay and response time to the exposed data. Another comparison of the performance of Gigabit Ethernet and ATM network technologies using modeling and simulation was done. Real-time voice and video conferencing type traffic were used to compare the network technologies in terms of response times and packet end-to-end delays. While ATM is a 53-byte frame connection-oriented technology, Gigabit Ethernet is a 512-byte frame (minimum) connectionless technology. The performance analysis indicated that the performance of ATM network is still very good as observed by [Jason,Khodai and Rashid, 2010]. But it does not keep up with the Gigabit Ethernets small delay time. Hence Gigabit Ethernet provides better performance than ATM as a backbone network, even in networks that require the transmission of delay sensitive traffic such as video and voice.

The use of network connecting devices plays an important role in the network design. Various network scenarios were designed by changing the network devices like Hub, Switch and Ethernet cables using the network simulation software. The performance of the network was analyzed using various performance metrics like Delay and application response time, Traffic sink, Traffic source and packet size. It was observed that the throughput improved and collisions decreased when the packet size is reduced as pointed out by [Ikram, 2009].

The choice of network simulator is very important for accurate simulation analysis. A comparative study of two network simulators: OPNET Modeler and NS-2 for packet level analysis was presented by [Gilberto and Marcos, 2010]. Both discrete events and analytical simulation methods were combined to check the performance of simulator in terms of speed while maintaining the accuracy. For performance testing of the network, different types of traffic like CBR (constant Bit Rate) and an FTP (File transfer protocol) were generated and simulated. Though both the simulators provide similar results, the —freeware version of NS-2 makes it more attractive to a researcher but OPNET Modeler modules gain an edge by providing more features.So, OPNET can be of use in academia i.e. advanced networking education according to [Theunis and Broeck, 2009]. Various scenarios like VoIP, WLAN or video Streaming were designed, simulated and also analysed analytically to check accuracy. This illustrated the broader insight the OPNET software can offer in the networking technologies, simulation techniques and its impact of applications on the network performance. III. IEEE 802.11

EIGRP is a distance vector routing protocol based on IGRP that offers the following improvements:

- Diffusing update algorithm (DUAL) used to determine whether a path advertised by a neighbor is loop-free and to identify alternate paths without waiting on updates from other routers.
- It stores all routes learned, not only the best one learned from neighbors.
- EIGRP actively queries neighbors when destinations become unreachable, and that leads to competitive convergence times.
- Use of Hello packets to maintain neighbor state leads to faster convergence.
- Use of reliable transport protocol for the exchange of updates eliminates the need for periodic, full updates.
- EIGRP uses complex metrics that provide flexibility in route selection.

2.1.2 Bandwidth utilization

Bandwidth refers to data carrying capability of a circuit or network, usually measured in bits per second (bps). "Bandwidth utilization is a measurement of how much bandwidth is used during a specific time period [Oppenheimer, 2009]". Utilization is commonly specified as a percentage of capacity. For example, a network-monitoring tool might state that bandwidth utilization on an Ethernet segment is 30 percent, meaning that 30 percent of the capacity is in use.

Bandwidth utilization for applications in KUCT was analyzed for optimum average utilization. KUCT use Fiber Optic as backbone technology and Fast Ethernet100 Mbps as LAN technology. Average bandwidth utilization was analyzed in detail on those technologies. Improper usage of network utilization degrades the network performance and therefore this is an important element to analyze.

2.1.3 Delay

"Delay is a measure of time differences in the transfer and processing of information [McCabe, 2008]". Therefore, users of interactive applications expect minimal delay in receiving feedback from the network. In addition, users of multimedia applications require a minimal variation in the amount of delay that packets experience. Delay must be constant for voice and video applications. Variations in delay, called jitter, cause disruptions in voice quality and jumpiness in video streams.

There are many sources of delay, including propagation, transmission, queuing, processing, routing and others. Propagation delay resulting from the finite speed of light, and the distance the signal must travel. [Abeysundara and Kamal, 2009] said that one measure of delay is the mean transfer time of packets. This is defined as the average time interval from the generation of a packet at the originating station until its complete reception at the destination. This is normally termed as queuing delay. Packet-switching delay refers to the latency accrued when bridges, switches, and routers forward data. The latency depends on the speed of the internal circuitry and CPU, and the switching architecture of the internetworking device.

1.4 Response Time

Response time is the amount of time between a request for some network service and a response) the request, [Oppenheimer, 2009]". Response time is also the network performance goal that sers care about most. Users recognize the amount of time to receive a response from the etwork system. They also recognize small changes in the expected response time and become rustrated when the response time is long. The 100-ms threshold is often used as a timer value for rotocols that offer reliable transport of data. For example, many TCP implementations etransmit unacknowledged data after 100 ms by default.

According to [Zhen and Yan, 2010], if a device's response time rises up to a value, which is ontinuously much higher than that in normal case or not just in peak time, it may indicate that he underlying network provides a poor performance and should be noticed. Therefore response ime of devices and applications in KUCT will be analyzed to check for performance level. Besides that guidelines can be provided to users to know on how long to wait depending on the size of files and the technologies in use (modems, high-speed digital networks, and so on).

2.1.5 Packet Loss Rate

The value of packet loss rate is also an important parameter in examining the network performance. Based on[Zhen and Yan, 2010], there were cases that packets loss occurred after a lasting higher response time. There were also cases that several critical devices had packet loss from the central core router. This situation implies that attention should be paid whenever the devices especially the central core one has continuous data loss. Packet loss rate also will be analyzed in KUCT to ensure there is no network problem exists.

2.2 Daisy Chain Network

A daisy chain is an interconnection of computer devices, peripherals, or network nodes in series, one after another. It is the computer equivalent of a series electrical circuit. The main advantage of the daisy chain is its simplicity and scalability. The user can add more nodes anywhere along the chain, up to a certain maximum (16 in SCSI-2 or SCSI-3, for example).

A daisy-chain network can be long in terms of the distance from one end to the other, but is not well suited to situations where nodes must be scattered all over a geographic region [McCabe, 2008]. In such a case, the cables must zig-zag around, and the overall length of the network can become huge compared with the actual distances between the nodes. This can cause the network to operate slowly for users near opposite ends of the chain, [Ikram, 2009].

2.3 Collapsed Backbone Network

The collapsed backbone network uses a switch as the single central connection point for multiple subnetworks. In a collapsed backbone, a single router or switch that makes up the collapsed backbone must contain multiprocessors to handle the heavy traffic going through it according to [Penttinen.A, 2007] The dangers of using this arrangement relate to the fact that a failure in the core switch can bring down the entire network.

2.4 Network Simulations

Network simulation is without a doubt one of the most predominant evaluation methodologies in the area of computer networks. It is widely used for the development of new communication architectures and network protocols. So-called network simulators allow one to model an arbitrary computer network by specifying both the behavior of the network nodes and the communication channels. For example, in order to investigate the characteristics of a new routing protocol, it is usually implemented in a network simulator. Afterwards, the routing behavior can be easily studied in different topologies, given the fact that the network topology is merely a set of simulation parameters.

The construction of real test beds for any predefined scenario is usually an expensive or even impossible task, if factors like mobility, testing area, etc. come into account. Additionally, most measurements are not repeatable and require a high effort. Therefore simulations are needed to bypass these problems. Simulators model the real world in a specific way. Their purpose is to ease the understanding of it, to surge its behavior and especially research its reactions on particular events. The goal of simulators is to achieve an "as real as possible" situation in order to make the simulation results realistic and therefore adaptable. Because it is impossible to collect and implement all the data and details playing a role within the real world, the simulators have to be trimmed. The difficulty is where to start cutting off details and where to end with it.

"Simulation case studies are conducted to analyze and improve the efficiency and effectiveness of manufacturing organizations, systems, and processes [McLean and Shao, 2003]". Simulation studies are designed to solve specific problems and get answers to specific questions. Thus, in this project network simulation will be used to analyze network performance in an organization.

Based on [Penttinen.A, 2007], normal analytical techniques make use of extensive mathematical models which require assumptions and restrictions to be placed on the model. This can result in an avoidable inaccuracy in the output data. Simulations avoid placing restrictions on the system and also take random processes into account; in fact in some cases simulation is the only practical modeling technique applicable. Therefore simulations provide easier method to analyze network systems in organizations. Besides that using simulations can save cost and prevent from wrong decisions taken in real world situation.

Network simulations can generate certain parameters such as simulated bandwidth, simulated delay, and simulated packet loss rate based on network design built in the simulator. Furthermore, analysts can study relationships between nodes, hosts and applications using simulations. So, this provides multiple design options before having to implement the outcome in real world.

Some of the network simulation tools are:

A. Enterprise network simulators

i) **OPNET:** Optimized Network Engineering Tool (OPNET) is a discrete event, object-oriented, general purpose network simulator. It provides a comprehensive development environment for the specification, simulation and performance analysis of computer and data communication networks. OPNET is a commercial network simulation package which is available for supporting both the teaching and research in educational institutions under the OPNET university academic program [9]. OPNET has several modules and tools, including OPNET modeler, planner, model library, and analysis tools [10]. It is widely used in the network industries for performance modeling and evaluation of local and wide-area networks.

The main strengths of OPNET include a comprehensive model library, modular model development, high level of modeling detail, user-friendly GUI, and customizable presentation of simulation results. However, OPNET is a very expensive package (license maintenance fees are also high), and its parameter categorization is not very transparent.

ii) **QualNet Developer:** QualNet Developer ('QualNet') is a distributed and parallel network simulator that can be used for modeling and simulation of large networks with heavy traffic . The QualNet consists of QualNet scenario designer, QualNet animator (visualization and analysis tool), QualNet protocol designer (protocol skeleton tool), QualNet analyzer real time statistical tool), and QualNet packet tracer (visualization and debugging tool). QualNet is a commercial version of the open source simulator called GloMoSim. The main strength of QualNet is that it supports thousands of nodes and run on a variety of machines and operating systems. It has a comprehensive network relevant parameter sets and allows verification of results through by inspection of code and configuration files. However, QualNet does not have any predefined model constructs.

iii) **NetSim:** NetSim is available both commercial and academic versions, and can be used for modeling and simulation of various network protocols, including WLANs, Ethernet, TCP/IP, and asynchronous transfer mode (ATM) switches NetSim allows a detailed performance study of

Ethernet networks, including wireless Ethernet. The effect of relative positioning of stations on network performance, a realistic signal propagation modeling, the transmission of deferral mechanisms, and the collision handling and detection processes can also be investigated . The main strength of NetSim is that the package can be run on a variety of operating systems. However, the use of NetSim is limited to academic environments only.

iv) **Shunra Virtual Enterprise (Shunra VE) 5.0**: Shunra VE is a hardware-based simulation environment having an advantage of high speed than the software-based simulation. The network impairments supported are the latency, bandwidth, jitter, packet loss, bandwidth congestion and utilization. StormCather enables the replay and capture of network activities. StormConsole used as the interface to StormAppliance, creates the network model . The main strength of Shunra VE include hardware-based system, good support, empirical model and uses real-life appliances. However, it is a very expensive package and requires a good network infrastructure for up and running.

B. Open source network simulators

i) **Ns-2**: Ns-2 is an object-oriented discrete-event network simulator originally developed at Lawrence Berkeley Laboratory at the University of California, Berkeley, as part of the Virtual InterNetwork Testbed (VINT) project. It was primarily designed for network research community for simulating routing algorithms, multicast, and TCP/IP protocols. The Monarch project at Carnegie Mellon University has extended the ns-2 with support for node mobility . Ns-2 is written in C++ and uses OTcl as a command and configuration interface. The main strength of ns-2 is its availability for download on a variety of operating systems at no costs. Authors of research papers often publish ns-2 code that they used, allowing other researchers to build upon their work using the original code. This is particularly useful to academia, specifically Master's and Doctoral students who are looking for a tool for network modeling and performance evaluation. The main weakness of ns-2 is the lack of graphical presentations of simulation output data. The raw data must be processed using scripting languages such as 'awk' or 'perl' to produce data in a suitable format for tools like Xgraph or Gnuplot . Another disadvantage of ns-2 is that it is not a user-friendly package because of its text-based interface, and many student researchers point out that ns-2 has a steep learning curve.

ii) **GloMoSim:** It is a library-based parallel simulator, developed at the University of California, Los Angeles, for mobile wireless networks. It is written in PARSEC (Parallel Simulation Environment for Complex System), which is an extension of C for parallel programming. GloMoSim is a scalable simulator that can be used to support research involving simulation and modeling of large-scale networks with thousands of nodes. The main strength of GloMoSim is its scalability to support thousands of nodes and executing simulation on multiple machines. Although GloMoSim was designed for both wired and wireless networks, currently it supports wireless networks only.

iii) **OMNeT++:** It is a modular component-based discrete event simulator. It uses building blocks called modules in the simulator. There are two types of modules used in OMNeT++, namely, simple and compound. Simple modules are used to define algorithms and are active components of OMNeT++ in which events occur and the behavior of the model is defined (generation of events, reaction on events). Compound modules are a collection of simple modules interacting with one another.

The main strengths of OMNeT++ include GUI, object inspectors for zooming into component level and to display the state of each component during simulation, modular architecture and abstraction, configurable, and detailed implementation of modules and protocols. However, OMNeT++ is a bit slow due to its long simulation run and high memory consumption. OMNeT++ is also a bit difficult to use.

iv) **The Georgia Tech Network Simulator:** The Georgia Tech Network Simulator (GTNetS) can be used to develop moderate to large-scale simulation models by using existing network simulation tools. Because of the object-oriented methodology, the model developed under GTNetS can be extended easily to support new networking paradigm. The main strength of GTNetS is that the design of GTNetS closely matches the design of real network hardware and therefore with a little knowledge of networking, the model can be constructed and simulated. However, it is still under ongoing development.

v) **AKAROA:** AKAROA is a fully automated simulation tool developed at the University of Canterbury, Christchurch, New Zealand. The main design goal was to run existing simulation programs in multiple replications in parallel (MRIP) scenario. AKAROA accepts an ordinary sequential simulation program and automatically launches the number of simulation engines requested by a user. AKAROA-2 is the latest version of AKAROA, which can be used in teaching in addition to research. The main strength of AKAROA is its MRIP to run simulation faster. However, AKAROA is a bit difficult to use.

Table 1

Name/Version	OPNET IT GURU	ns-2 2.27	J-Sim (formerly JavaSim) 1.3
Availability	Highly expensive, commercial software (no publicly available trial). Available with source code for simulation modules (except for restricted protocols). Academic software also available free	Open-source software, available with full source code, validation tests and examples.	Open-source software, available with full source code and examples
Support	- excellent manual - mailing list (maintenance license required)	good manual - publicly available mailing list	- good manual - publicly available mailing list - source code and
Topology/ Scenario	- GUI, XML, imports (e.g., HP OV) - "scenario" parameters - C/C++	- OTcl scripts (or C++)	- Tcl scripts (or Java) (as of 1.3) - OTcl or Java (future releases)
Extensions (components)	- C/C++	- OTcl (higher level) - C++ (lower level)	- Java (as of 1.3) - also OTcl for higher level (future releases)
Simulation mode	- synchronous, single-threaded, discrete event queue based, with zero event processing time, fully deterministic - multithreaded, discrete event queue based, with zero event processing time - distributed simulation: HLA (High-Level Arch.)	- synchronous, single-threaded, discrete event queue based, with zero event processing time, fully deterministic - parallel/distributed version available (Parallel /Distributed NS, PDNS)	- synchronous, single-threaded, with zero event processing time, fully deterministic - multithreaded, "real-time process-based," with event processing times taken into account, nondeterministic
Brief summary (with subjective assessment)	- fast, „heavyweight" - expensive commercial software - ready, high-fidelity equipment and protocols models; a "reference" simulator - unique (e.g., military) features; widely used in NATO projects	- fast, quite modern, free - OTcl binding -simplified equipment models - many recent TCP mechanisms implemented for ns-2 - currently most popular in research projects	- scalable, modern, free - Tcl/Jacl binding (OTcl/Jacl) - simplified equipment models - new simulation paradigm (active components)

Table 2

Simulator	Type	Deployment mode	Network impairments	Network protocol supported
OPNET	Commercial /academic	Enterprise	Link models such as bus and point-to-point (P2P), queuing service such as Last-in-First-Out (LIFO), First-in-First-Out (FIFO), priority non-preemptive queuing, round-robin.	ATM, TCP, Fiber distributed data interface (FDDI), IP, Ethernet, Frame Relay, 802.11, and support for wireless.
QualNet	Commercial	Enterprise	Evaluation of various protocols.	Wired and wireless networks; wide-area networks.
NetSim	Commercial /academic	Large-scale	Relative positions of stations on the network, realistic modeling of signal propagation, the transmission deferral mechanisms, collision handling and detection process.	WLAN, Ethernet, TCP/IP, and ATM
Shunra VE	Commercial	Enterprise	Latency, jitter and packet loss, bandwidth congestion and utilization.	Point-to-point, N-Tier, hub and spoke, fully meshed networks.
Ns-2	Open source	Small-scale	Congestion control, transport protocols, queuing and routing algorithms, and multicast.	TCP/IP, Multicast routing, TCP protocols over wired and wireless networks.
GloMoSim	Open source	Large-scale	Evaluation of various wireless network protocols including channel models, transport, and MAC protocols.	Wireless networks.
OMNeT++	Open source	Small-scale	Latency, jitter, and packet losses.	Wireless networks
P2P Realm	Open source	Small-scale	Verify P2P network requirements, topology management algorithm or resource discovery.	Peer to peer (P2P)

GTNetS	Open source	Large-scale	Packet tracing, queuing methods, statistical methods, random number generators.	Point-to-Point, Shared Ethernet, Switched Ethernet, and Wireless links.
AKAROA	Open source	Small-scale	Protocol evaluation.	Wired and wireless networks, Ethernet.

2.5 Existing Systems

According to the undertaken survey carried out KUCT has a several parameters that was carried out in this research. Several cases were fronted in order to achieve the project objectives.

2.5.1 Case 1. KUCT has daisy chain network where switches are interconnected in series. One switch is hooked into another as shown below.

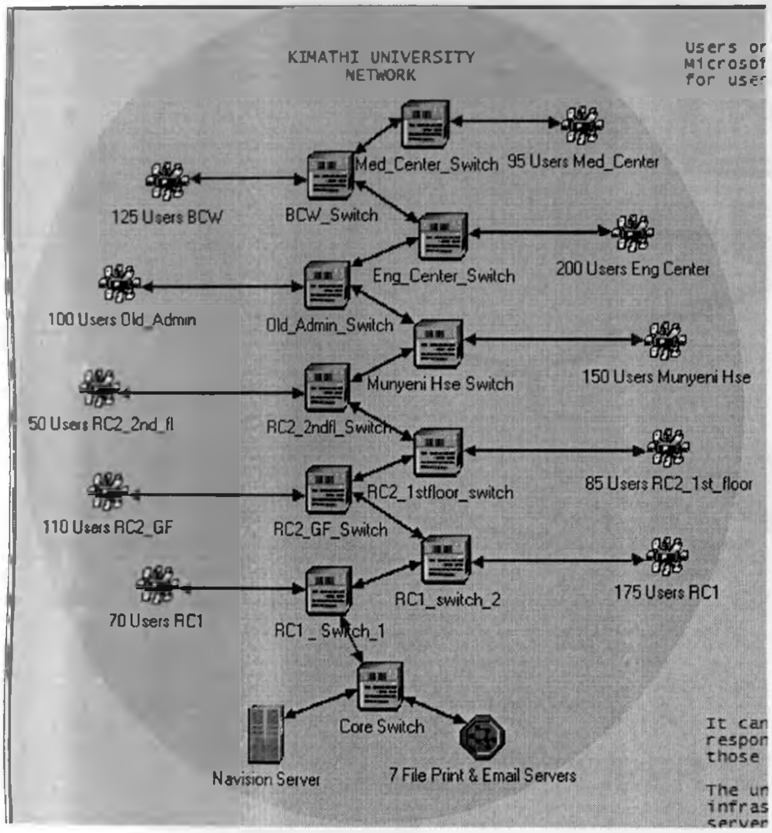
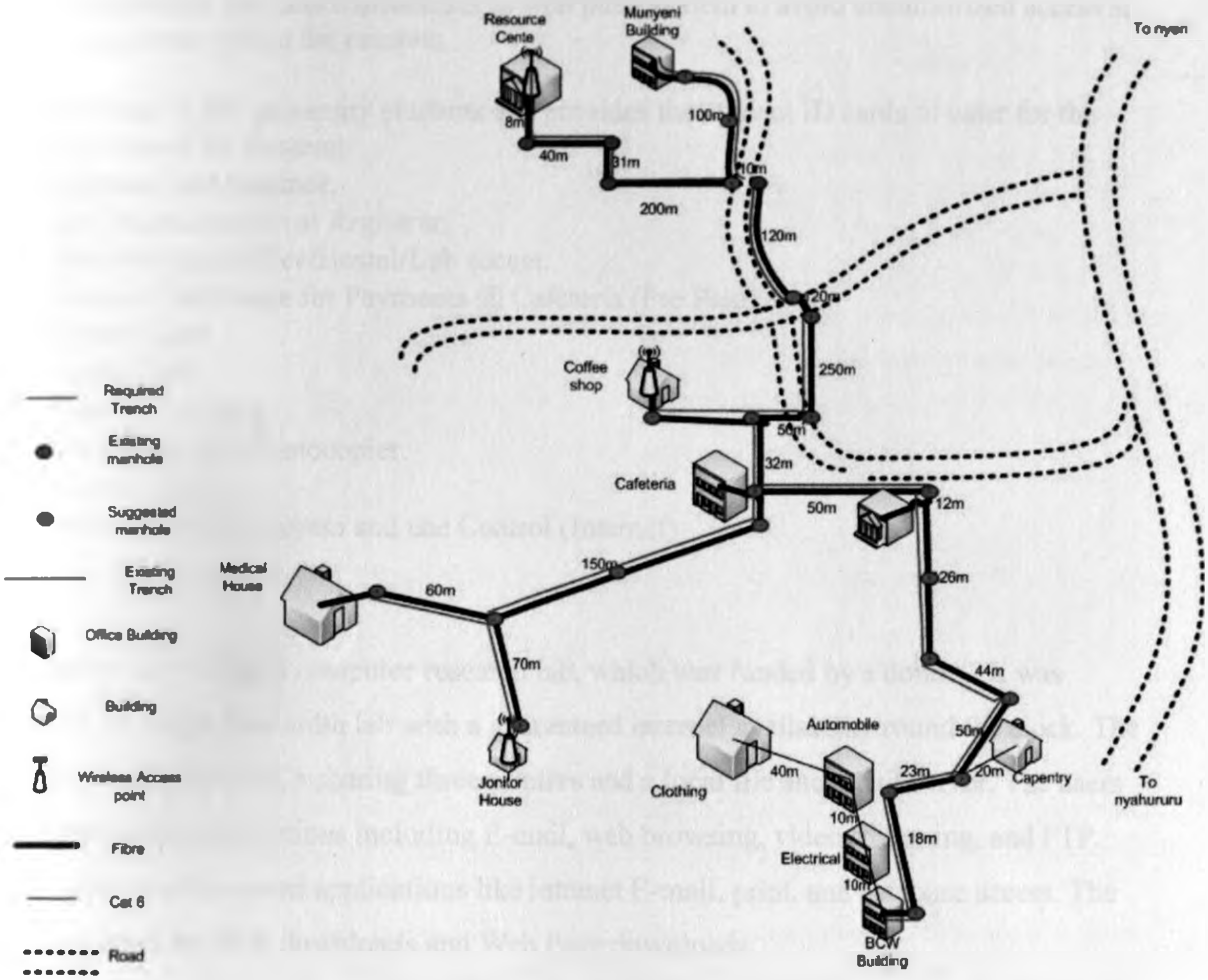


Fig. 2.1 shows the daisy chain network which is at KUCT and how the switches are interconnected up to the core switch which sits next to the Navision Server.



KIMATHI FIBER NETWORK DIAGRAM

Fig 2.2 the figure above outlines the backbone fiber network layout in KUCT where all the major buildings have been interconnected by fiber connection.

2.5.2 Case 2. Kimathi University network connects to the Internet through a CISCO PIX Firewall. Users use various online applications including e-mail, web browsing, and smart card authorization to essential facilities like Library, cafeteria , main entrance, e.t.c.
However, some users are doing illegal file transfers for pirated music and videos. There is no firewall policies which has been implemented as it is the case of now. Thus, no illicit traffic is blocked.

Kimathi University's most critical application is Smart card authorization which works as One Card for all the facilities and payment functionalities within and outside the university. The objective is having Cash Less transactions as well put a system to avoid unauthorized access at various secure areas within the campus.

KUCT has about 4,500 university students and provides the student ID cards to cater for the following Scope of the System:

- Campus Card Issuance.
- Fee Personalization at Registrar.
- Gate/Building/Office/Hostel/Lab access.
- Campus Card usage for Payments @ Cafeteria (Pre Paid).
- Library Card.
- Health Card.
- Electronic Voting.
- Integration with Photocopier.
- Alumni Card.
- Network services access and use Control (Internet)

2.5.3 Case 3: KUCT has a computer research lab, which was funded by a donor . It was intended to be a high bandwidth lab with a guaranteed internet availability round the clock. The LAN consists of 20 user PCs sharing three printers and a local file and email server. The users run different online applications including E-mail, web browsing, video streaming, and FTP. Users also run locally served applications like intranet E-mail, print, and database access. The two critical tasks are FTP downloads and Web Page downloads.

CHAPTER THREE: METHODOLOGY

This methodology modeled towards investigating modern computer networks performance in academic setting with emphasis on critical network parameters like response time and load balancing challenges associated with bandwidth link utilization and erratic traffic behavior. In order to perform a comparative assessment, eight networks will be constructed using OPNET simulation software. All these eight different networks will be a representative of the current network setup vis a viz the proposed network design with firewall and enhanced load balancing configured. This will enable an investigation on the behaviour of the network in respect to identified performance metrics enabling the determination of any possible benefits of undertaking redesign and configuration process.

The new features which will be introduced in the proposed model will include:

i. Enhanced load balancing configuration of routers in network using normal distribution to increase network efficiency.
ii. A collapsed backbone infrastructure with firewall configuration to increase response times in FTP and HTTP activities.

The design of the representative network is based on information gathered from the case study academic institution. The choice to undertake the research in academic institution was motivated by the readiness with which such institutions share information towards academic pursuits and the consideration that apart from examination processing in such institutions, most of the other information can be availed upon request. Academic institutions also share similarities in respect to applications they use, traffic characteristics as well as user behaviour which is not the case in other enterprises providing similar or related services.

Applications which suffer load congestion and response time are sentive to delays, jitter, packet loss and latency. All these parameters are influenced by bandwidth and the way network adapts itself to changes in traffic behaviour. These parameters will provide the point of comparison between the suggested networks

3.1 Assumptions in construction of the representative model network

a) Workstations have similar features in terms of memory, processing power and same applications load.
b) Traffic generation patterns are the same for all the work stations apart from those devices configured to generate burst traffic.
c) The devices provided by the simulation software are a true representation of the actual devices as would be encountered in a typical production network.

3.2 Limitations

a) Internet bandwidth options were not as varied as in real life.

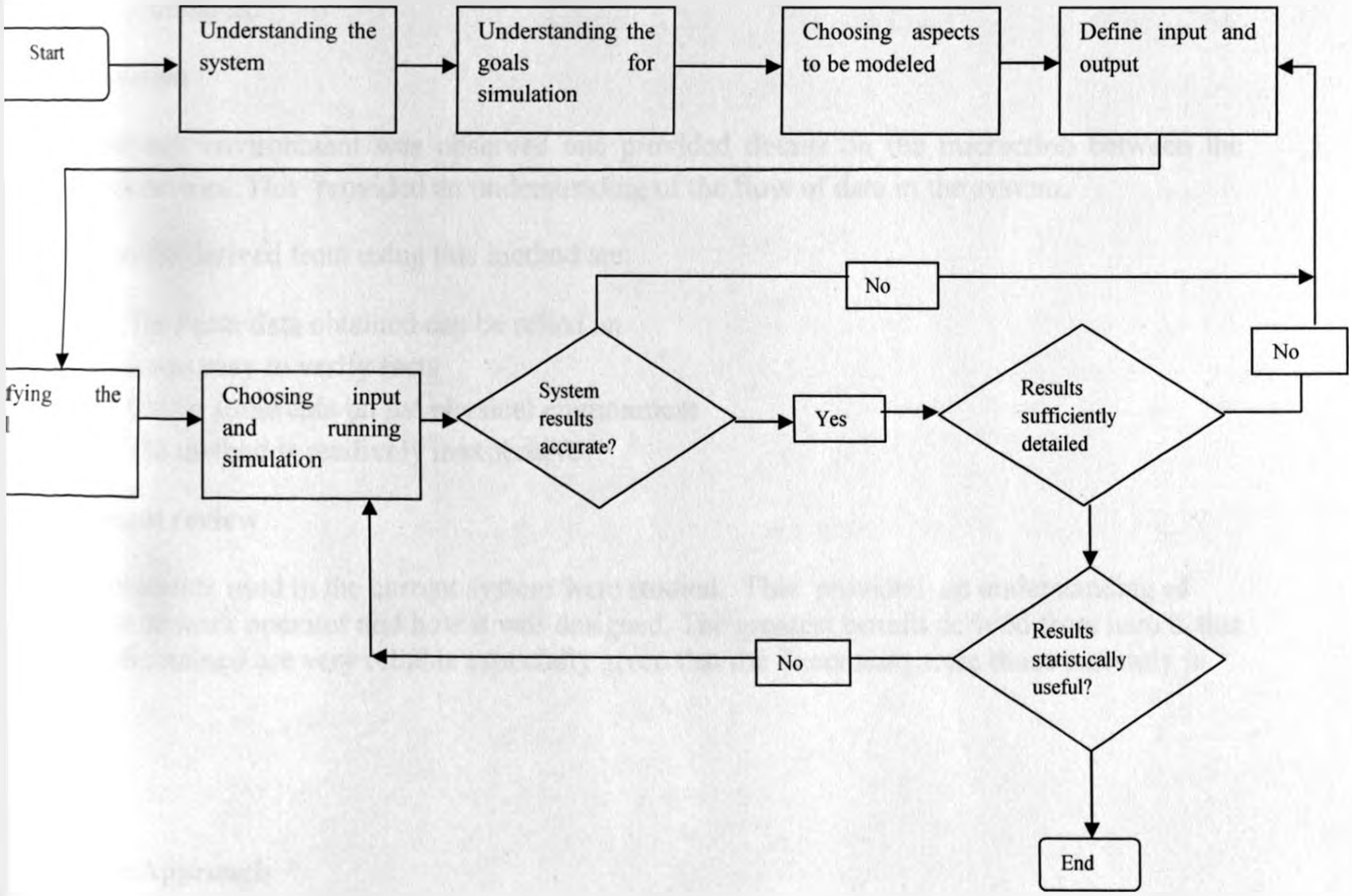
b) Due to time factor, it was not possible to comprehensively explore and use the most features of the simulation software.

c) The reference materials available in the use of the simulation software were limited in scope.

d) The OPNET Academic Edition simulation software has a maximum of 50 million event

3.3 Design methodology

Fig 3.1 below show the methodology which has been utilized when developing the simulations of the research project.



This section describes the project design that has been adopted in order to develop the research to determine responses to the research questions posed in earlier section of this document and also the process employed towards meeting the research objectives. This research evaluates the performance of a proposed campus network against a model representation of the current status of our campus network using the following facets:

a) Existing network topology will be designed for the organization based on the information gathered.
b) Logical design will include representation of selected technology, application flows within and between the blocks and structure of the topology.
c) Physical design will include specific devices, equipment placement, wiring scheme and cabling implemented in the network.
d) This phase also will provide suggested network design to improve existing network performance in the organization. All network designs will be implemented in the form of simulation.

Observation

The network environment was observed and provided details on the interaction between the network devices. This provided an understanding of the flow of data in the system.

The benefits derived from using this method are:

a) The Facts/data obtained can be relied on
b) It was easy to verify facts
c) Obtain some data on the physical environment
d) The method is relatively inexpensive

Document review

The documents used in the current system were studied. This provided an understanding of how the network operates and how it was designed. The greatest benefit derived from here is that the facts obtained are very reliable especially given that the documents were those currently in use.

3.4 The Approach

This research design can be broken down into four main sections:

a) Gathering information about status of the campus network.
b) Model design and configuration of the representative Testbed network.
c) Model design and configuration of proposed network.

d) Generation of results (Global and Selected individual device statistics).

e) Analysis and comparison of generated results.

3.5 The Planning

a) Gather information about background of this project.
b) Feasibility study was conducted to identify existing problems, constraints, and determines objectives of this project. Scope, expected output and project significance was clearly stated in this phase.
c) Reviews done on existing projects and approaching methods was studied to gain more knowledge about this project.
d) Project methodology, hardware and software requirements were also identified in this phase.

3.6 The Analysis

a) Requirements analysis was conducted on user, hosts, application and network requirements.
b) Existing network infrastructure was characterized.
c) Organization's current applications and hosts were analyzed and documented in this phase.

1. **Implementation**

a) Network designs prepared in previous phase were built in OPNET IT GURU simulation software to analyze the network performance.
b) Network performance was analyzed on bandwidth utilization, delay, response time and packet loss rate.
c) Characteristic of traffic flow was analyzed to include distribution of critical resources in the network and segment workload.

Software Requirement

Software tools required in this project are:

a) OPNET Modeller

OPNET Modeller software is used as main tool in this project to simulate network performance characteristics of case study organization. OPNET (Optimized Network Engineering Tools) is a tool for modelling, simulation and performance analyzing of communication networks and communications protocols.

The tool has been used by developers to:

- Develop new protocols.
- Optimize existing protocols.
- Study the performance of existing protocols in different network
- Topologies during varying traffic loads.
- Evaluate competing protocols.

OPNET models are hierarchical. At the lower level, a state-transition diagram encodes the behaviour of an algorithm or protocol with embedded code based on C language constructs. At the middle level, discrete functions such as buffering, processing, transmitting, and receiving data packets are performed by separate objects, some of which relay on an underlying process model. These objects, called models, are created or modified using the Node Editor and connected to form a higher-level network model. At the highest level, node objects based on underlying node models are deployed and connected by links to form a network model. The network model defines the scope of the simulation, and it is used as a "table of contents" when the simulation execute, and it is bound together from its discrete components. The component of a process model includes a finite state machine (FSM) diagram with embedded C statements, and various blocks containing codes for variable declaration, macros, constants, and function definitions. These components are collectively termed Protoc, since they define a variant of the C language specialized for protocols and distributed algorithms.

OPNET Modeller is a sophisticated workstation-based environment for the modelling and performance evaluation of communication systems, protocols and networks. OPNET features include: graphical specification of models; a dynamic, events scheduled Simulation Kernel; integrated data analysis tools; and hierarchical, object based modelling.

Hardware Requirement

Hardware requirement for this project is a personal computer. Minimum requirements for the personal computer are: Pentium 4 Microprocessor or better.

- 60GBHDD
- 512 MI3 to 1 GB RAM
- 52 x CD ROM Drive

Recommended requirement on the personal computer are:

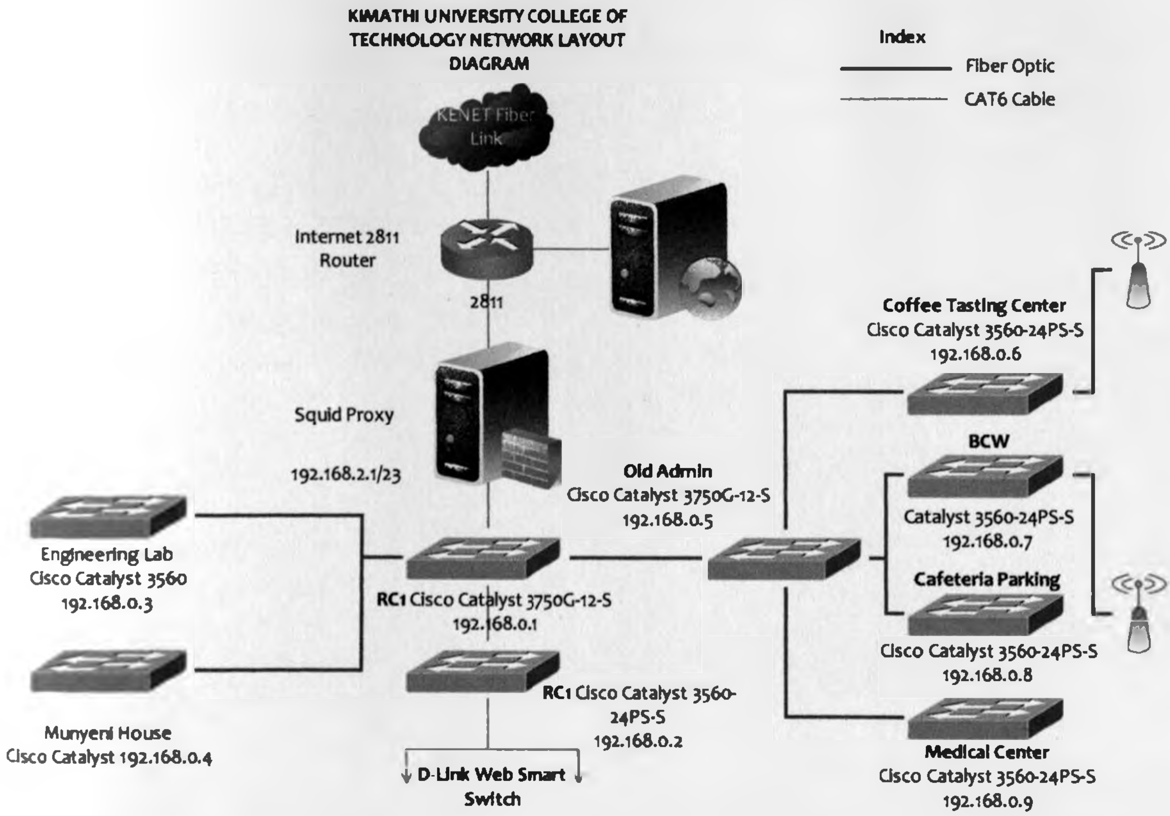
- Core 2 Duo Centrino Intel Processor, 1.66GHz
- 120 GB HDD
- 1GB RAM
- Dual layer DVD/CD Drive

2. **Testing**

a) Data from performance analysis of existing network and suggested network was tested using simulations for validity.

b) The result (performance data and graph) was then used to provide comparison between existing network characteristics and suggested network characteristics. Proposed network characteristics should be better and provide solution to improve network performance in the organization

Fig 3.1 below shows the existing network diagram for KUCT where it outlines the core switches placement logically on the network.



CHAPTER 4: SIMULATIONS AND EXPERIMENTS

4.1 Daisy Chain Versus Collapsed Backbone Architecture

This simulation scenario outlines the application performance of two different network architectures: Daisy Chain (it is the current network at the campus) and Collapsed Backbone Network. The simulation shows a collapsed backbone data network in which there is a core switch in the Resource Center 1. The core switch is linked directly to a workgroup switch on each building. Another option is to link the switches in a daisy chain. In this approach, the Resource Center 1 core switch is linked directly to the Resource Center 2 switch; the Resource Center 2 switch is linked directly to the Munyeni House switch, and so forth. This simulation shows the application latency (response time) introduced by connecting network switches in different ways.

Monte Carlo analysis was used and essentially a means of estimating some property of a probability distribution in that use of random numbers and probability to solve problems.

One begins with one or more state variables defining a point in the space of all possible outcomes, known as the sample space.
Monte Carlo is usually applied when the sample space is so large that it is not practical to apply the algorithm to all possible states.

4.1.1 Simulation 1 (Daisy Chain)

Fig 4.1

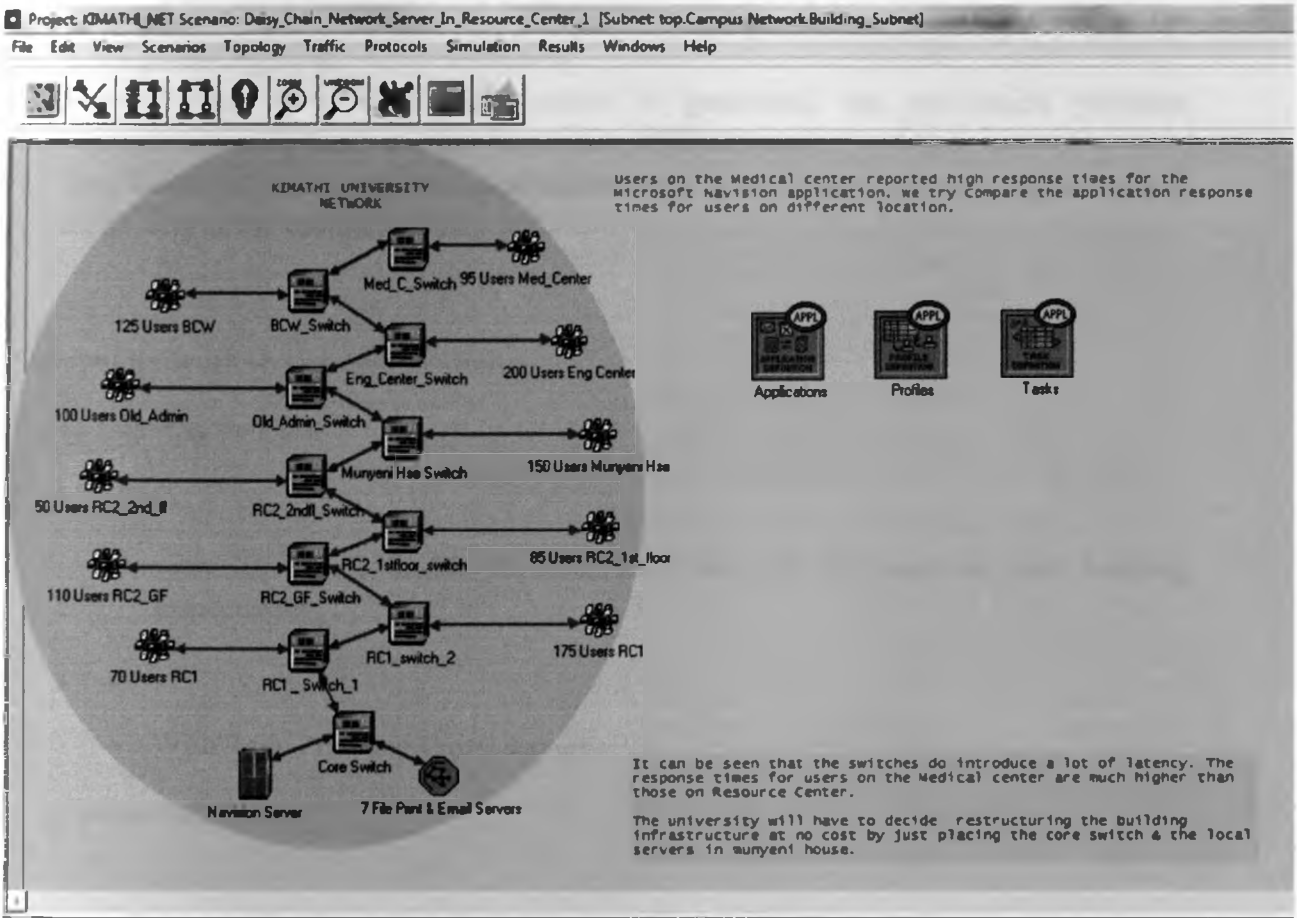


Fig 4.1 shows the daisy chain network which is at KUCT and how the switches are interconnected up to the core switch which sits next to the Navision Server.

Traffic Generation Parameters

The following characteristics of traffic were specified for each of the traffic sources.

Start Time: The time at which the application that generates the traffic starts.

- ***ON/OFF State:*** The application generates traffic when it is ON, and stops sending the traffic when it is OFF. The application alternates between ON and OFF state. When an application is set to be ON for some specified amount of time then OFF for 0 seconds, this implies that it will always be ON.
- ***Packet Generation Arguments:*** when the application is ON, the following attributes of the type of traffic generated were specified.

- ***Inter-arrival Time:*** the time between each packet the application generates (sends) a packet, waits for the inter-arrival time, then generates the next packet, waits for the inter-arrival time and so on.
- ***Packet Size:*** the size of each packet. The average packet size is set to 1000 bytes but the actual packet size may vary considerably.
- ***Segmentation Size:*** after each packet is generated, the application performs segmentation, with the maximum packet size of 1500 bytes.
- ***Stop Time:*** the time at which the application stops. This application will continue running for as long as the simulation runs.

Current network device composition

- 11 Ethernet switches
- 10 LANs
  - with 70, 175, 110, 85, 50, 150, 100, 200, 125, 95 users on each building respectively.
- 1 subnet
  - With 7 file Print and Email servers
- 1 Database Server

Fig 4.12

Component Type	Location/Placement	Number of computers/ Switches
Ethernet Switches	KUCT	11 Switches
LAN	Resource 1	70 Computers
LAN	Resource 1 1st Floor	175 Computers
LAN	Resource 2 GFloor	110 Computers
LAN	Resource 1st Floor	85 Computers
LAN	Resource 2nd Floor	50 Computers
LAN	Munyeni House	150 Computers
LAN	Old Admin	100 Computers
LAN	BCW	200 Computers
LAN	Engineering Center	125 Computers
LAN	Medical Center	95 Computers

Fig 4.12 shows the summary of placement and the number of computers at each location which can be related to figure 4.1

Fig 4.2

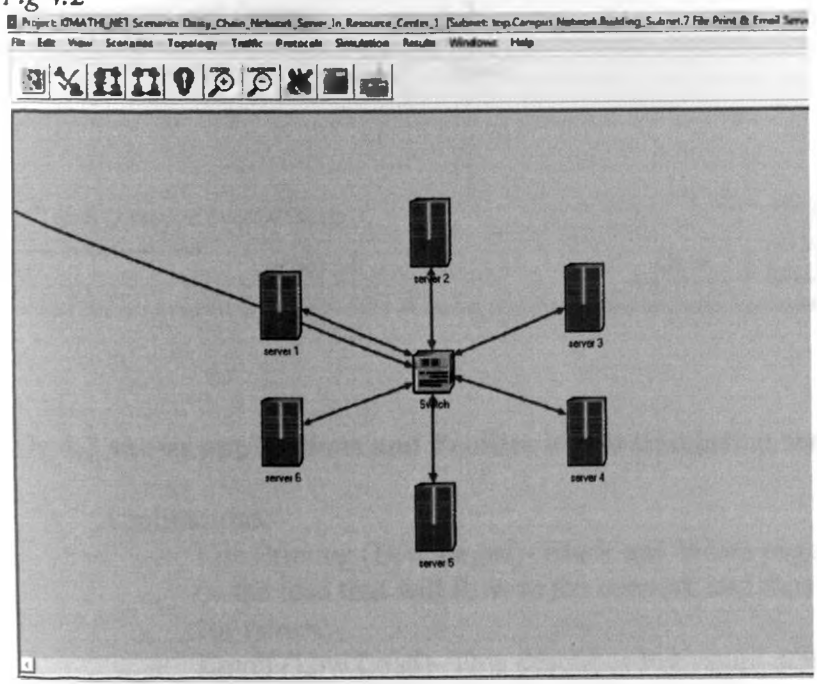


Fig 4.2 shows a subnet: has been used to create hierarchy of network levels.
A double-click on the subnet named **"7 File Print & Email Servers"** to enter it shows servers clustered together. This is the number of the server that contributed to the load on the prescribed network.

Also the LAN icons represent several workstations connected in a switched LAN. The number of workstations has been set by editing its attributes.

Fig 4.3

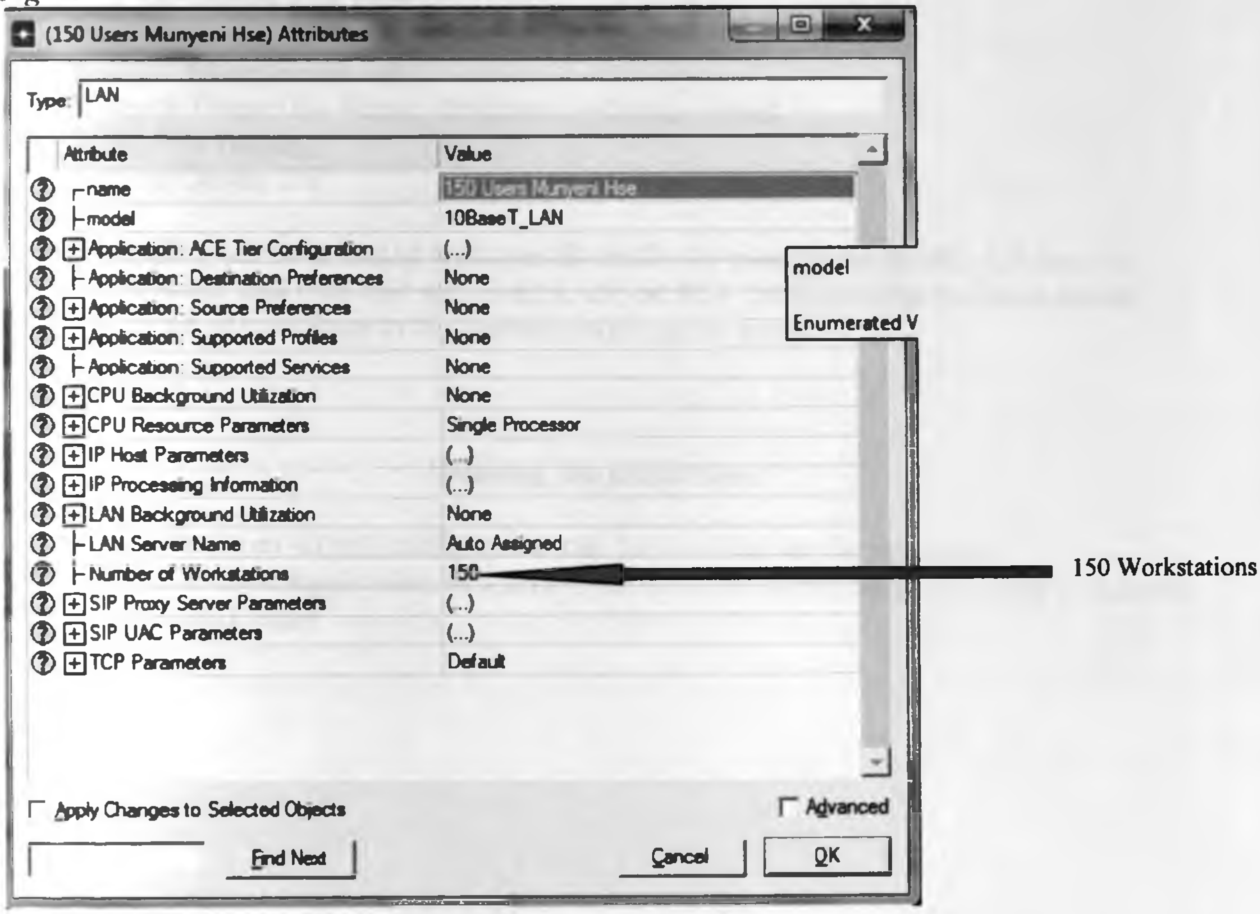


Fig 4,3 shows applications and Profiles in this simulation scenario:

- Applications:
  - File Printing (B/W pages)- Black and White pages for printing this will form part of the load that will flow in the network and thus constitute necessary parameters for review.
  - Email (Low Load)- This describes low email activity from Munyeni House.
  - Database (High Load)- The database load for this will be high since the Navision software has alot of users on that end.

Profiles on LANs

- RC_GF: Email, DB
- RC1_1st Floor: Email
- RC2_GF: Email, File Print
- RC2_1st Floor: File Printing
- RC2_2nd Floor: Email, DB
- Munyeni House,Old Admin, Engineering Center: Email
- BCW: File Printing
- Medical Center: DB
-

The above profiles has been loaded with specific traffic for example on the RC_GF there is Email and Database load onto that part of the LAN; on RC1_1st Floor what has been loaded there is just Email to contribute to the load and so on and so forth.

Running the simulation

The simulation has been set and configured to run for one hour on the simulator.
The Microsoft Navision Application Response Time for users on buildings Resource 1, Munyeni House, and medical Center.

4.1.2 Simulation 2 (Daisy_Chain_Network_Server_On_Resource2_2nd Floor

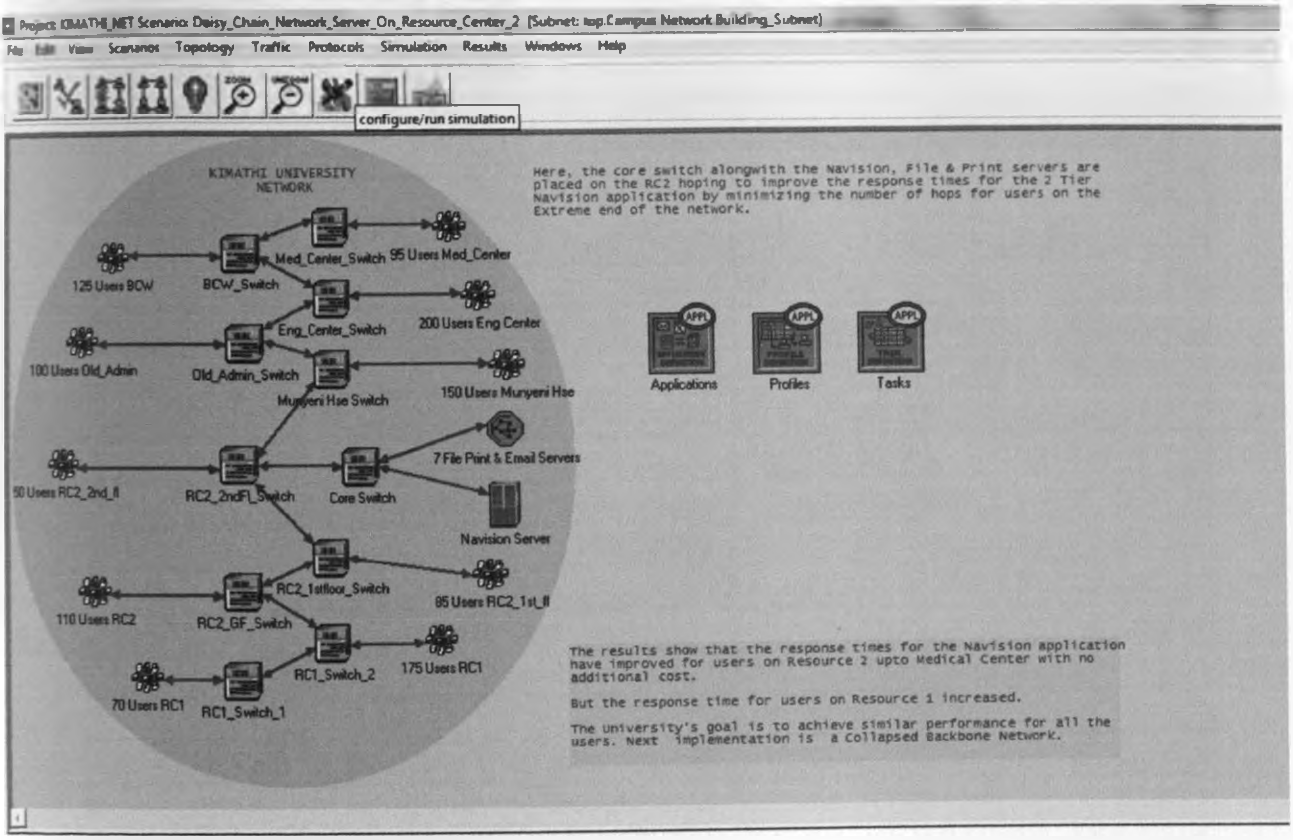


Fig 4.4

4.1.3 Simulation 3 (Collapsed backbone network.)

To achieve similar performance in terms of response time for all users a collapsed backbone kind of network is simulated where all distribution switches are hooked onto directly to the core switch.

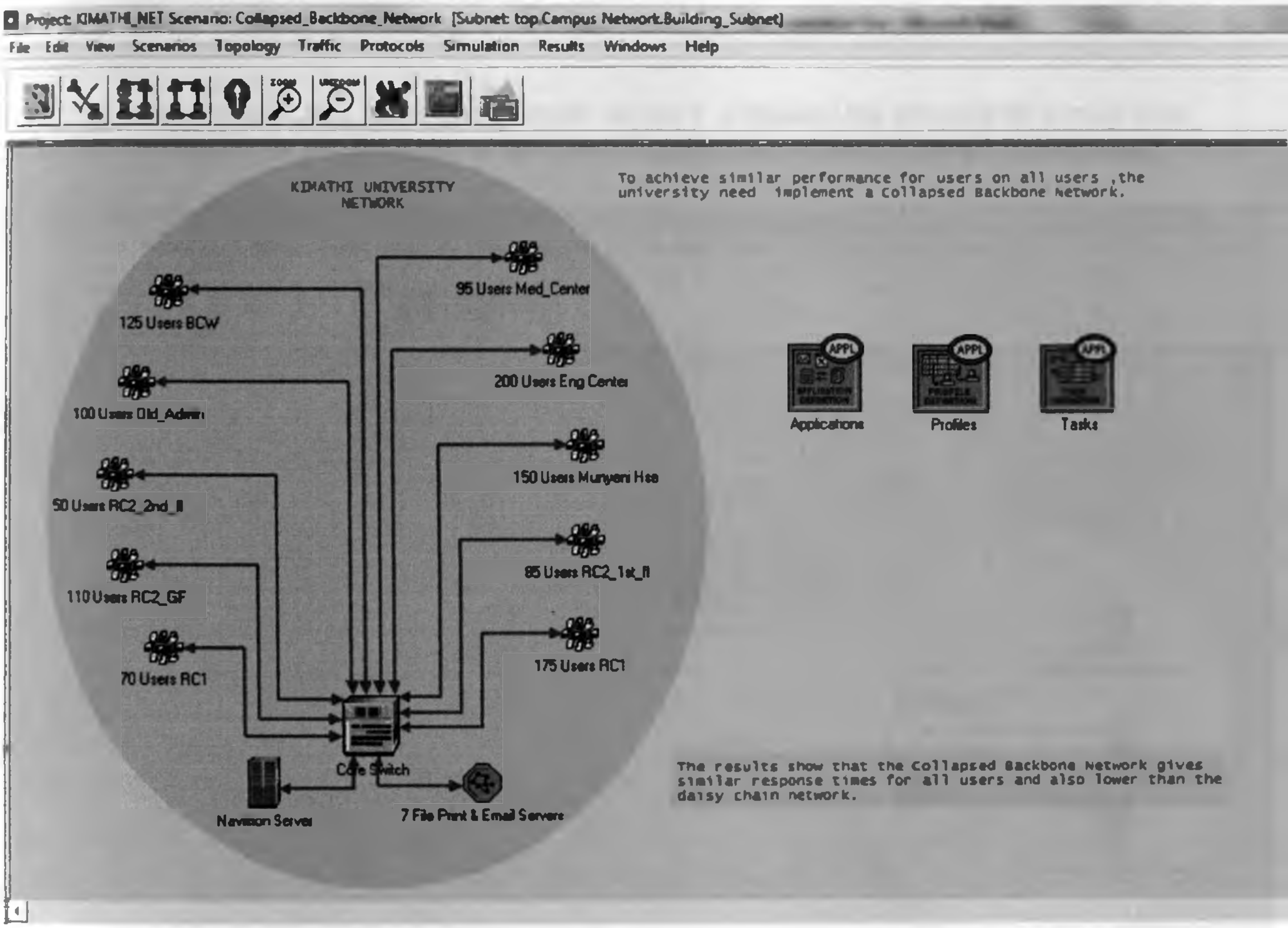


Fig 4.5 shows a collapsed backbone network with all the users connected to the core switch.

4.2 Simulation 4. Analyzing Firewall Policies to Manage Network Traffic

Using the proposed collapsed backbone network we have simulated the network for a busy hour of the day to evaluate the performance of the critical application without Firewall Implemented.

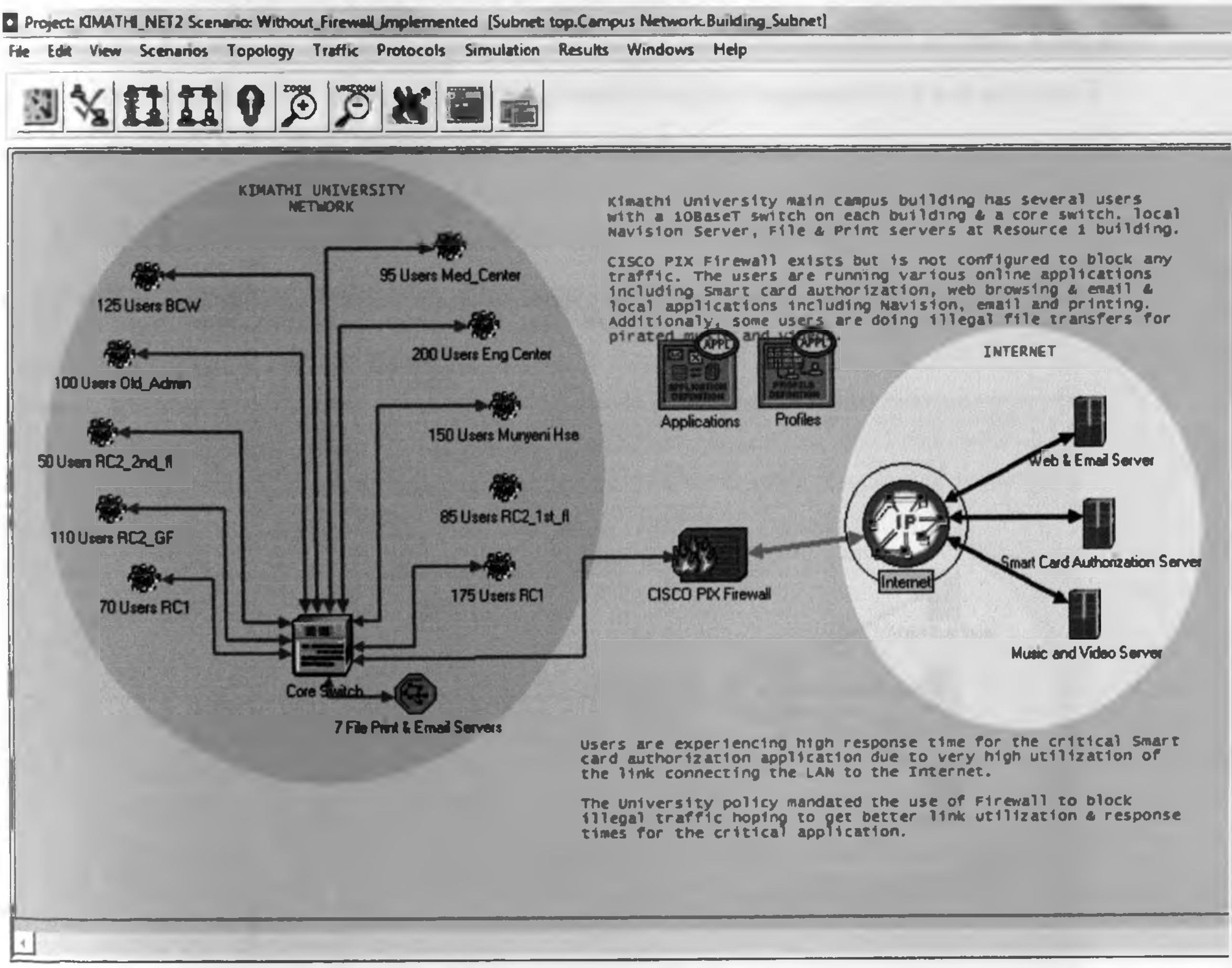


Fig 4.6 shows a collapsed backbone network without firewall implemented

4.3 Simulation 5. Evaluating Application Performance across a WAN in high bandwidth research lab

The two critical tasks are FTP downloads and Web Page downloads. The link utilization between the LAN and the ISP were simulated because of the aforementioned critical . After an initial assessment, the LAN was split into two smaller switched segments and add an extra T1 link between the LAN and the ISP to double the available capacity.

Fig 4.7

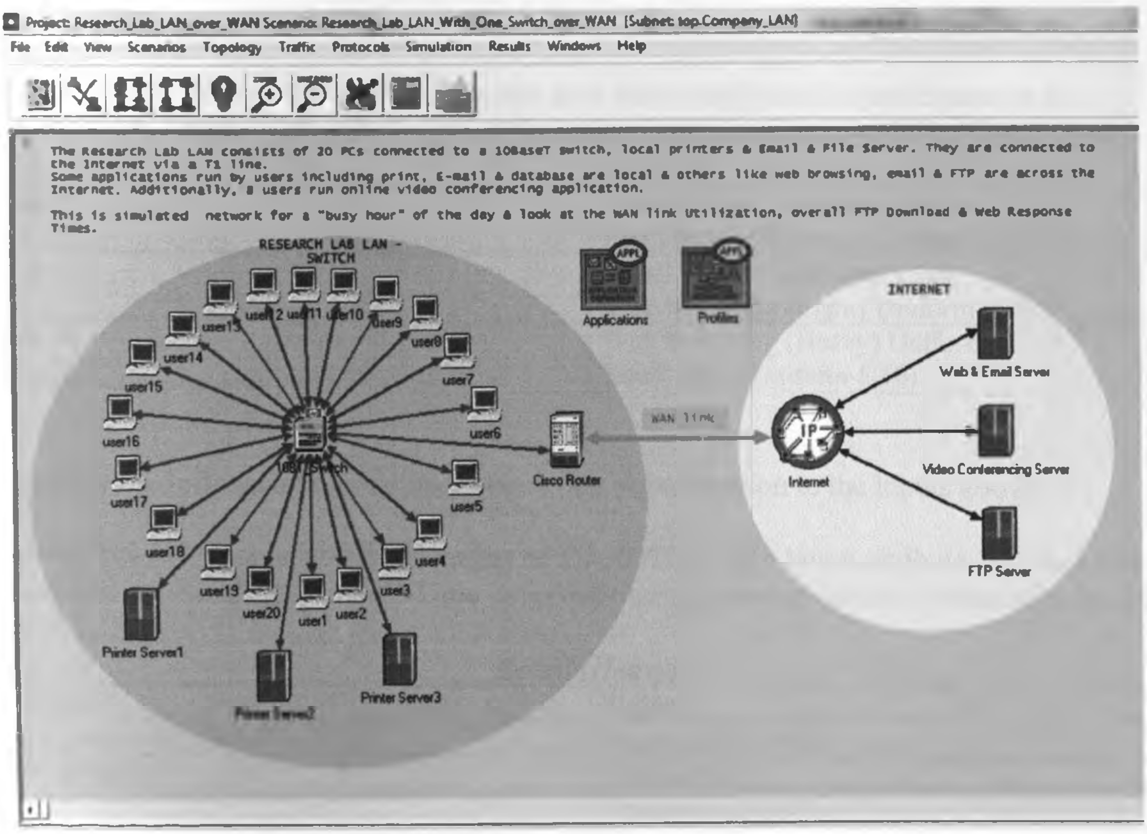


Fig 4.7 shows the Research Lab LAN with 20 PCs connected to a 10BaseT switch, local printers & Email & File Server. They are connected to the Internet via a T1 line.
Some applications run by users including print, E-mail & database are local & others like web browsing, email & FTP are across the Internet. Additionally, 8 users run online video conferencing application.

This is simulated network for a "busy hour" of the day & look at the WAN link Utilization, overall FTP Download & Web Response Times.

4.4 Simulation 6. Simulation of the Research_Lab_LAN_With_Two_Switches_Over_WAN.

The LAN is segmented into 2, each having a switch & connected to Internet via 2 T1 lines.

Main inputs for this simulation

1. 20 users on the research lab assigned to different groups based on their usage.

2. profiles as depicted by the table below.

Table 3.1 below defines the applications that have been configured to participate on the simulation e.g Group 1 has email application which is light using the uniform distribution

Group 1	Email (Light) , Uniform (5,10) File Transfer (Heavy), Uniform (5,10)
Group 2	Email (Light), Uniform (5,10) Web Browsing (Light) Uniform (5,10)
Group 3	Web Brwosing (Heavy) Uniform (5,10) Email light (Uniform 5,10)

3. Application definition as predefined above (More explanation to the inputs above).

Table 3.2 below expounds on the meaning of ***Email (Heavy)*** in terms attribute and the value related to it e.g. Send Inter-arrival Time in seconds using exponential distribution of value 360.

Email (Heavy).

Attribute	Value
Send Inter-arrival Time (Sec)	Exponential (360)
Send Group Size	Constant (3)
Receive Inter arrival time (sec)	Exponential (360)
Receive Group size	Constant (3)
E-mail Size (bytes)	Constant (2000)
Type of Service	Best Effort (0)

The following 6 tables also expound on the above subject detailing the applications and how they have been built up.

Table 3.3

Email (Light).

Attribute	Value
Send Inter-arrival Time (Sec)	Exponential (3600)
Send Group Size	Constant (3)
Receive Inter arrival time (sec)	Exponential (3600)
Receive Group size	Constant (3)
E-mail Size (bytes)	Constant (500)
Type of Service	Best Effort (0)

Table 3.4

File Transfer (Heavy).

Attribute	Value
Command Mix (Get Total)	50%
Inter-Request Time (Seconds)	Exponential (360)
File Size (bytes)	Constant (50000)
Type of Service	Best Effort (0)

Table 3.5

File Print(Light).

Attribute	Value
Print- Interarrival	Expential (90)
File Size (bytes)	normal (3000,9000)
Type of Service	Best Effort (0)

Table 3.6

Web Browsing(Heavy).

Object Size (bytes)	No of objects
Constant (1000)	Constant (1)
Uniform Int (2000,13000)	Constant (7)
Type of Service	Best Effort (0)

Table 3.7

Web Browsing(Light).

Object Size (bytes)	No of objects
Constant (500)	Constant (1)
Small image	Constant (5)
Type of Service	Best Effort (0)

Table 3.8

Database (Medium)	
Attribute	**Value**
Transaction Mix (Queries/Total Transactions	100%
Transaction - Inter arrival time	Exponential (12)
Transaction Size (bytes)	Constant (512)

Fig 4.7.1

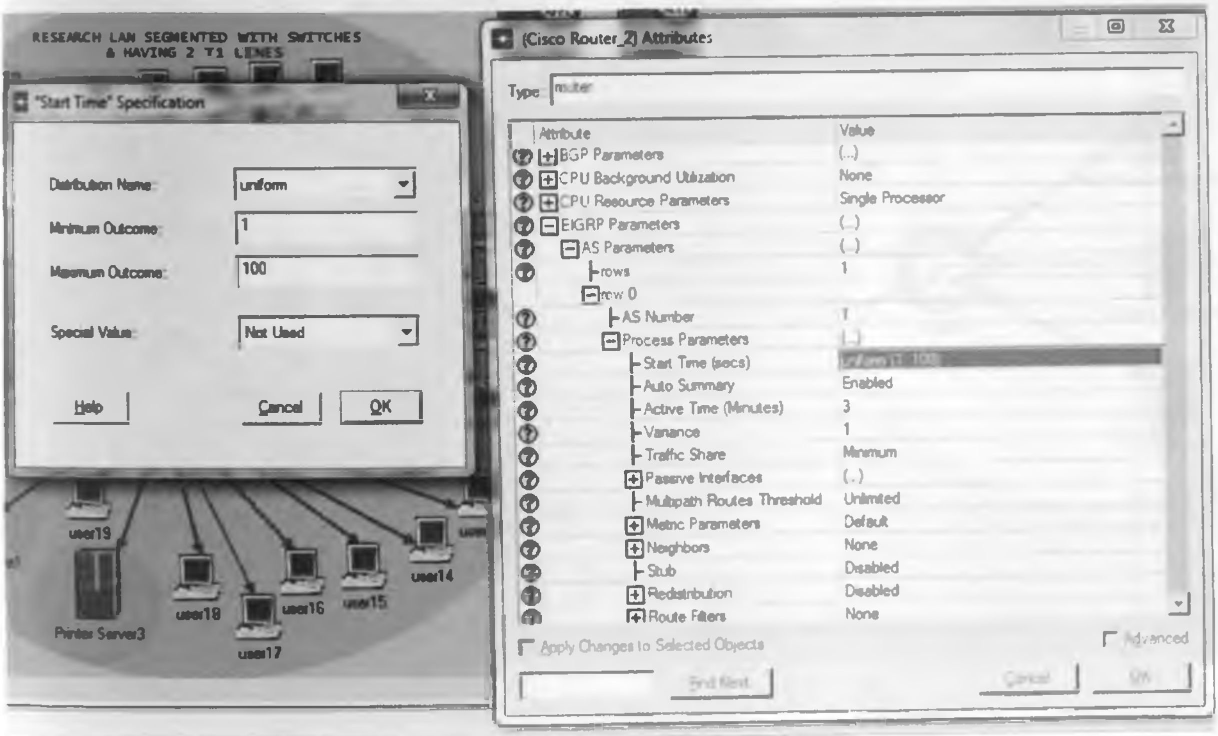


Figure 4.7.1 shows input parameters of the preconfigured Cisco router.

EIGRP is used to perform Load Balancing on the 2 WAN links.
What is compared in the 2 WAN link Utilizations, FTP Download & Web Response Times for a busy hour of the day.

Fig 4.8

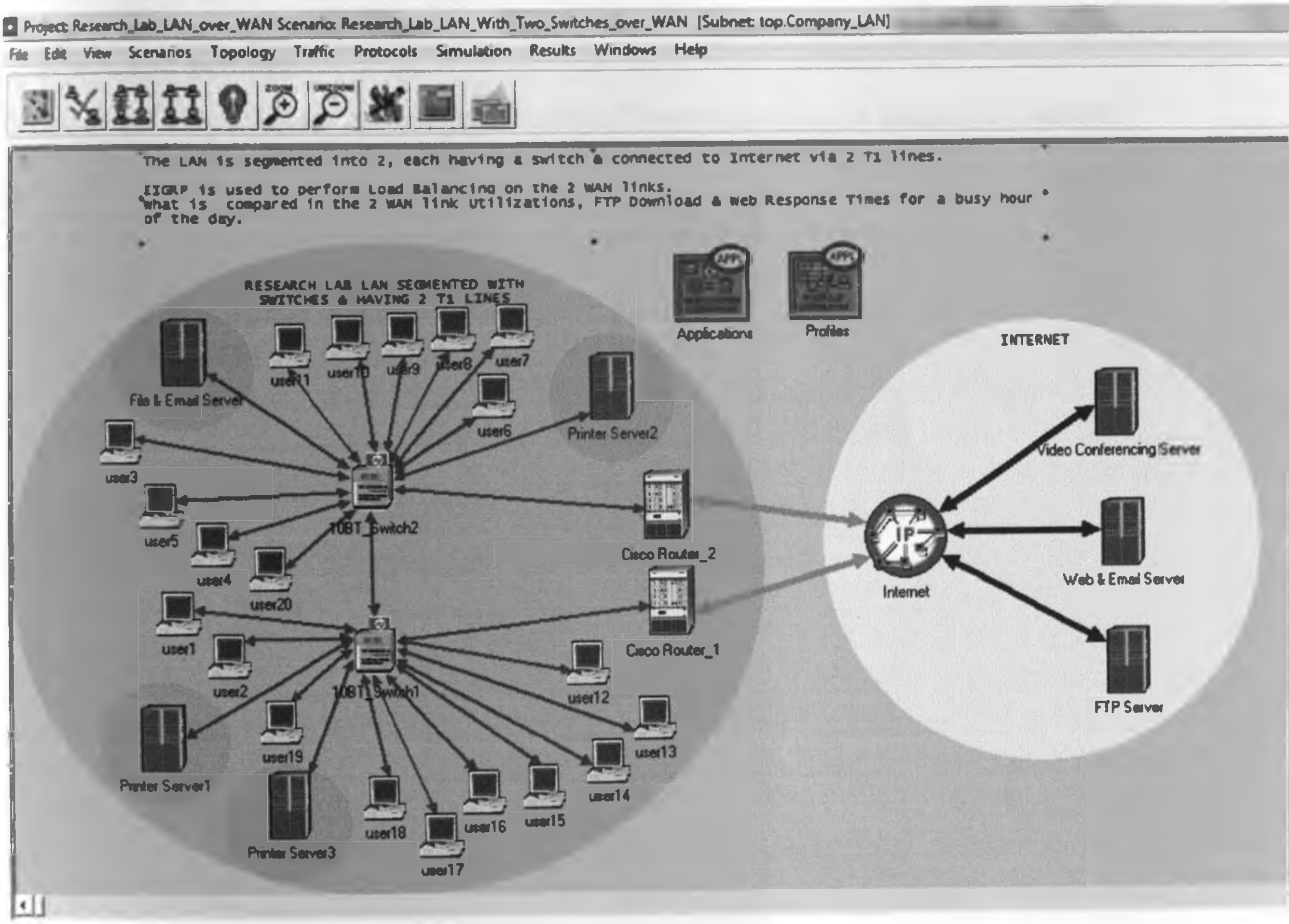


Fig 4.8 shows Research LAN Lab with two switches and two routers optimized for load balancing.

CHAPTER FIVE: RESULTS AND FINDINGS

5.1 Daisy chain network

The Medical Center 95 users Application Response Time when trying to access the database.

Fig 5.1

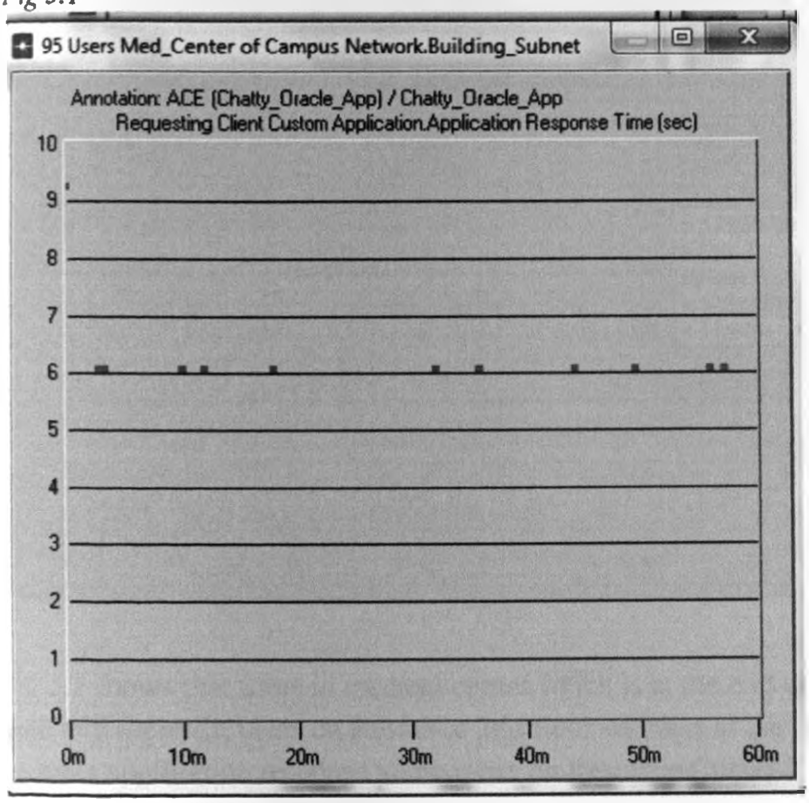


Fig 5.1 above shows the application response time is **6 seconds** on the client custom application after running simulation for one hour. this is done in medical center block which it is the end of the daisy chain.

This was repeated for 50 Users on Resource 2 Second Floor as well as 70 users on Resource 1 Ground Floor users.

Fig 5.2

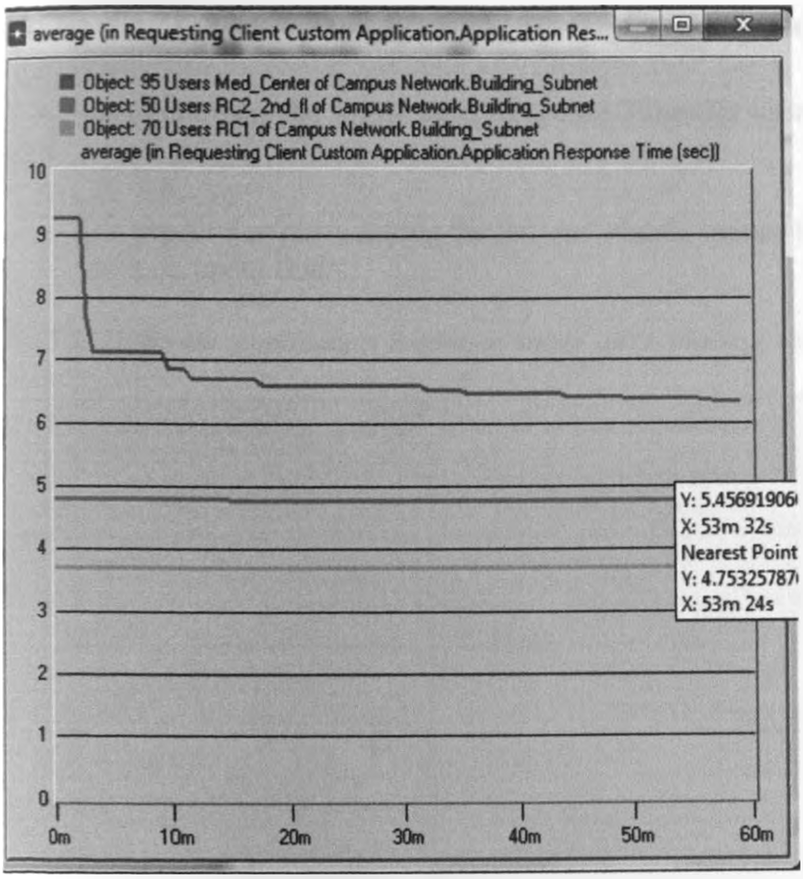


Fig 5.2 shows that users in medical center which is at the end of the chain network have response time of **6 seconds**, users on Resource 2nd floor which is at the center of the chain network have **5 seconds** application response while users on Resource Center 1 has less than **4 seconds** on client custom application reponse.

Now we have the statistics for users on all buildings on the same graph.

Our results are shown on the above graph.

1. As we can see, the Application **Response Time** is close to **6 seconds** for users in medical center.

2. It reduces as we move to the Resource 2. Users in Resource 1 have the least response times.
   This shows the amount of latency introduced by the switches.

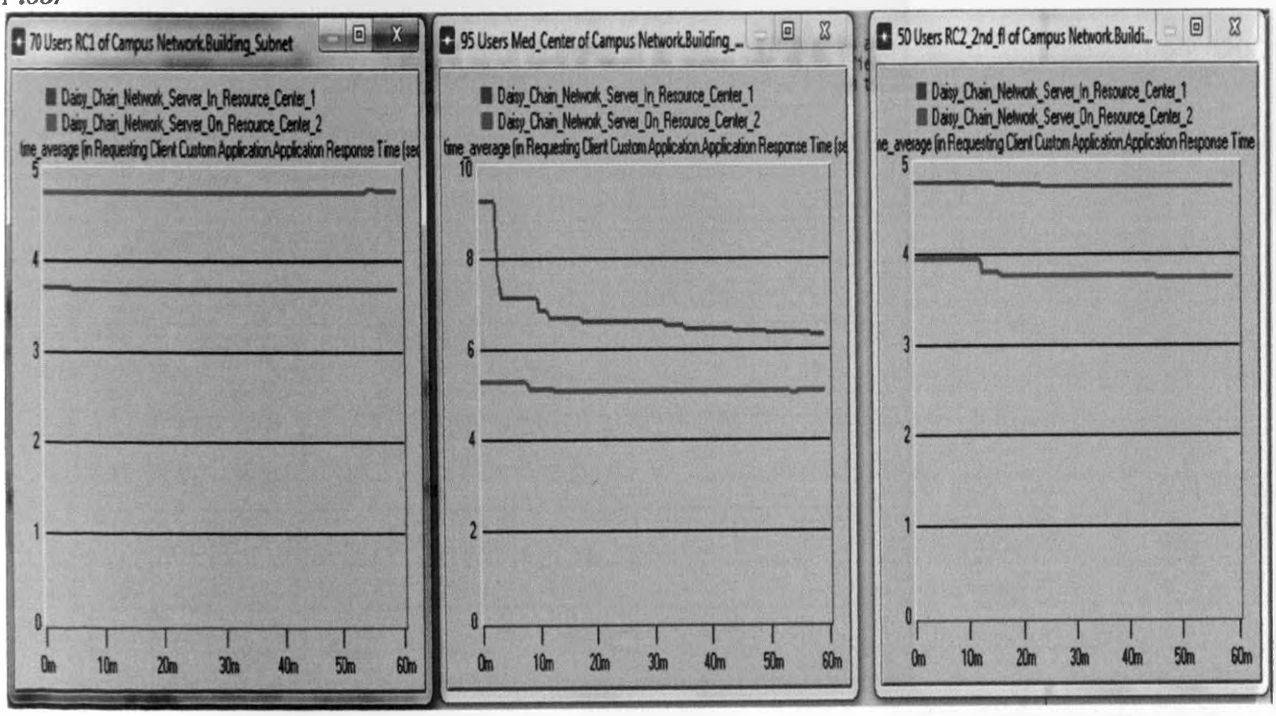
3. Users in medical center report high application response times. So the university decides to reduce the number of hops for the users on extreme end by moving the core switch and the servers to the Resource 2 2nd Floor.

5.2 Scenario 2 (Daisy_Chain_Network_Server_On_Resource2_2nd Floor

- Let us compare the Application Response Times for users on different buildings.

- We expect that restructuring the network should reduce the application response times for users on upper floors.

Fig 5.3. Different application response times after placing the core switch in Resource 2 2nd Floor



As expected, the Navision application Response Time went down for users on Resource 2 and Medical Center.

The users on Resource 1 suffered an increase in response time. The University decides to change the architecture from a Daisy Chain to a Collapsed Backbone network hoping to achieve the same application performance for all the users.

5.3 Scenario 3 (Collapsed backbone network.)

Fig 5.4

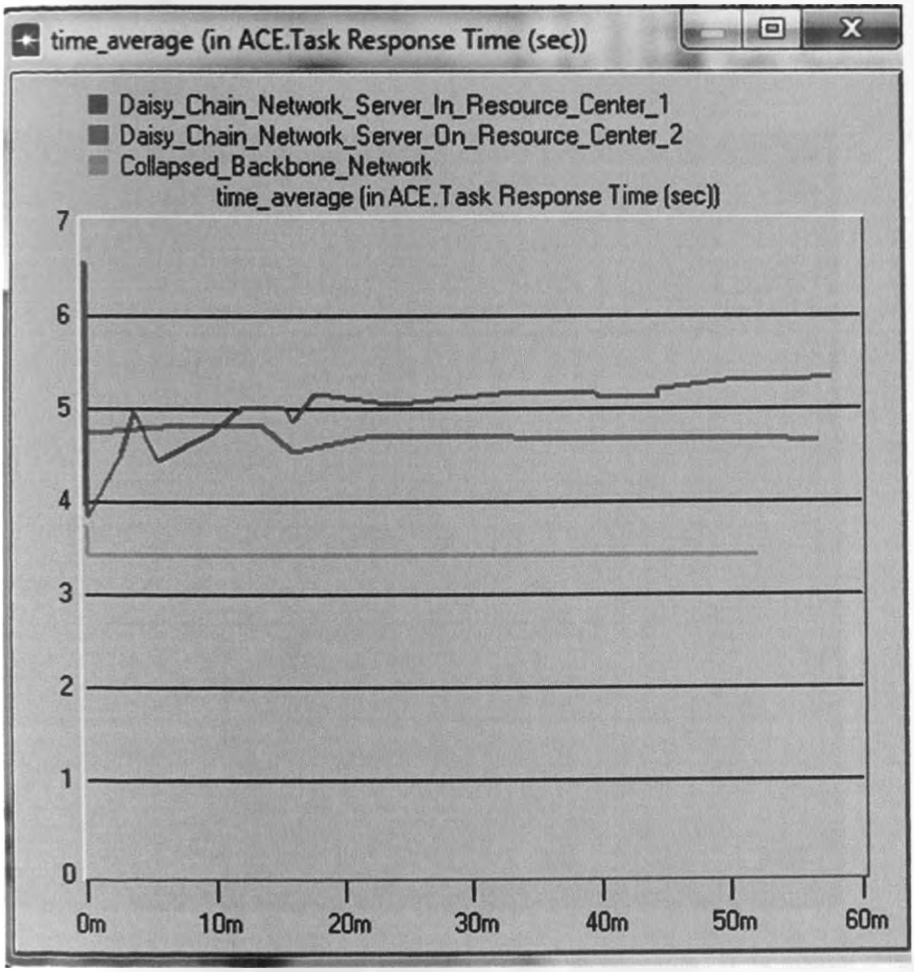


Fig 5.4 show the comparison of daisy chain network when the server is at Resource Center 1, daisy chain network when the server is at Resource Center 2 and collapsed Backbone Network. It is tested on *time average* in task response time as shown below:

- Daisy chain network when the server is at Resource Center 1 = **5.2 Seconds.**
- Daisy chain network when the server is at Resource Center 2 = **4.8 Seconds.**
- Collapsed Backbone Network= **3.5 Seconds.**

The findings show that the Collapsed Backbone Network gives similar response times for all users and also lower than the daisy chain network.

Simulation 4

5.4 Analyzing Firewall Policies to Manage Network Traffic

Fig 5.5

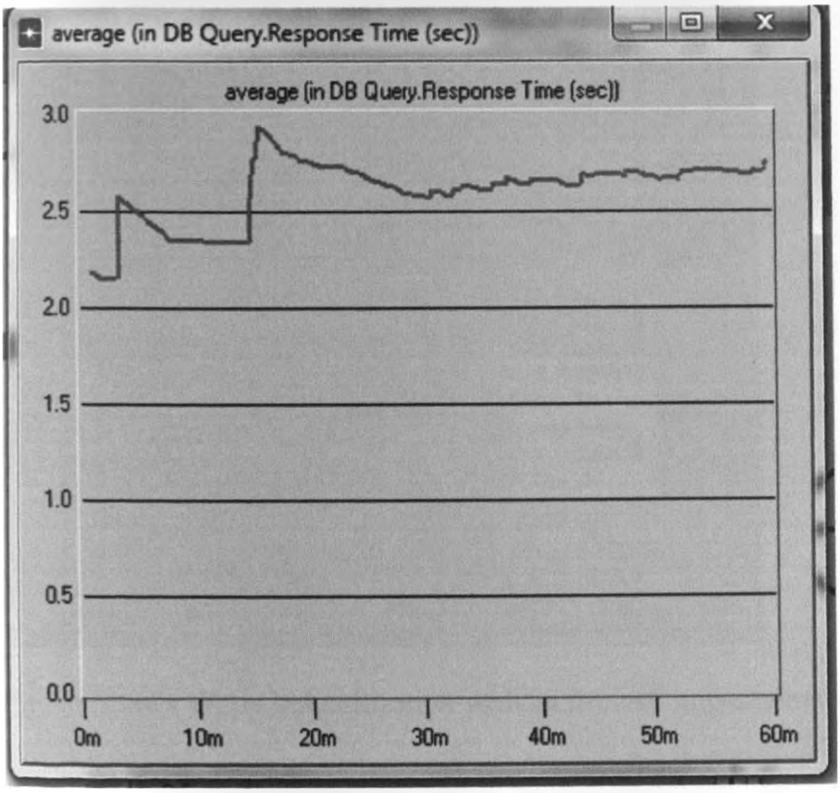


Fig 5.5, shows the Database response time in seconds. It is above 2 seconds when the firewall policy is not implemented to block the illegal traffic. The application **response time** on average is above **2 seconds**

Fig 5.6

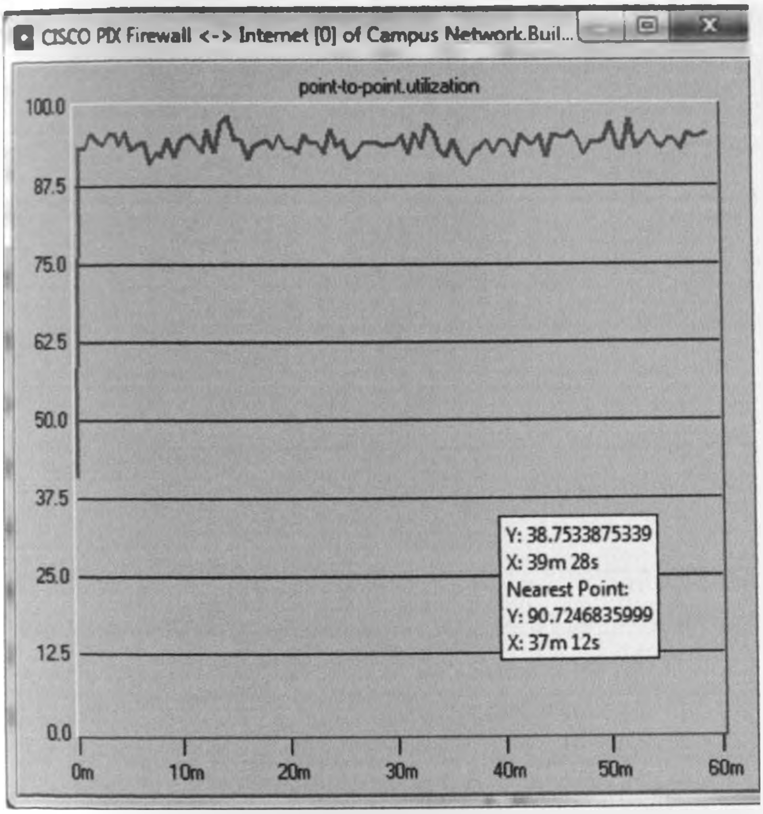


Fig 5.6 shows WAN link utilization without firewall implementation.

- The results show that the Smart Card Authorization Response Time is above the required limit of 2 seconds.
- Also the WAN link utilization is high which might contribute to unacceptable application response times.

The university decided configuring the firewall to block peer-to-peer file transfers to see its effect on the application performance.

Fig 5.7

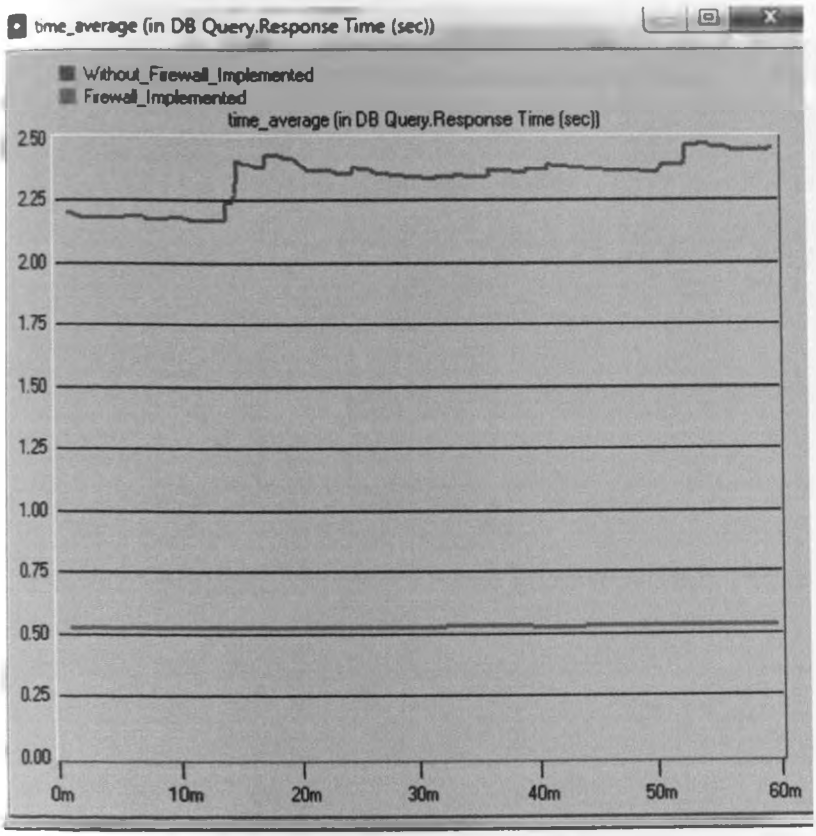


Fig 5.7 shows when the firewall is implemented using CISCO PIX firewall.

When comparing results response time on the database query it is about **0.5 seconds** when the firewall is implemented.

Fig 5.8

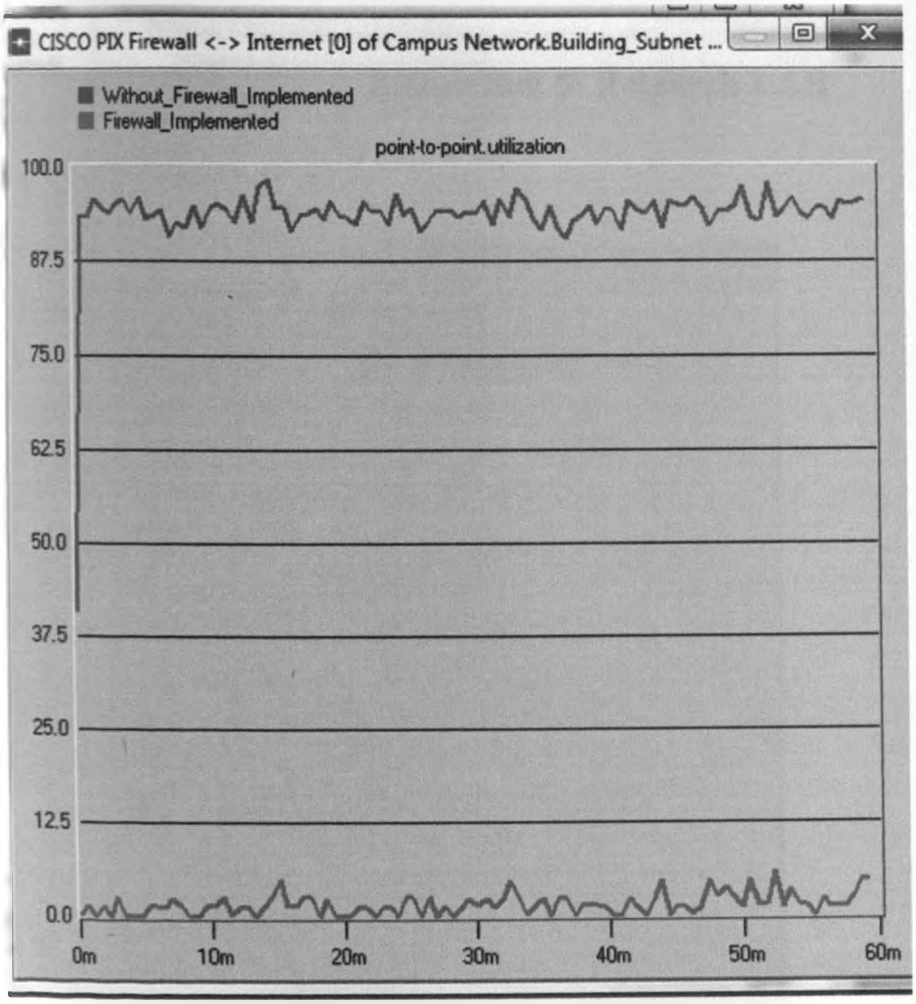


Fig 5.8 shows WAN link utilization after implementing the firewall. The utilization has gone drastically down which is shown on the red curve against the blue curve where WAN link utilization is high when the firewall policy is not implemented.

Findings:

1. As expected, the results show that implementing the firewall had a significant improvement in the credit card authorization application performance.
2. The utilization graph shows significant reduction in the WAN link utilization due to the firewall policy, thereby improving the application performance.
3. By mandating the firewall policy to stop illicit peer-to-peer file transfers, the university will be able to achieve the required performance for the critical Smart Card Authorization

Simulation 5: Research LAB

Fig 5.9

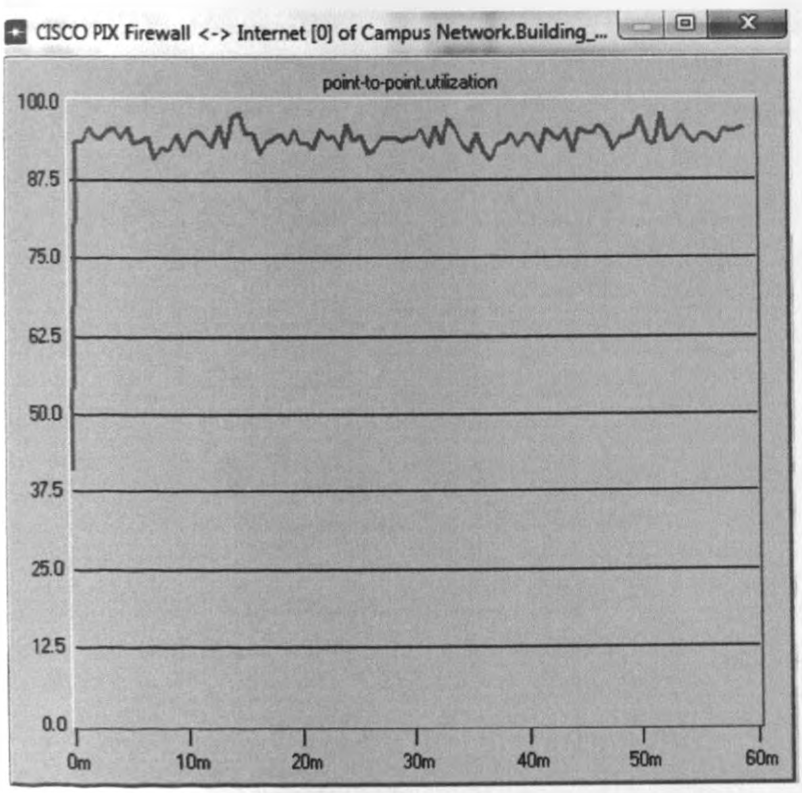


Fig 5.9 shows the LAN-WAN link utilization which is above **87.5 %** on point to point.

Comparing the results:

A Comparison the link utilizations, Web Application and FTP Download Response Times. The expectation is that the additional link to the ISP should reduce the application response times. The two links splits the link utilizations.

Fig5.10

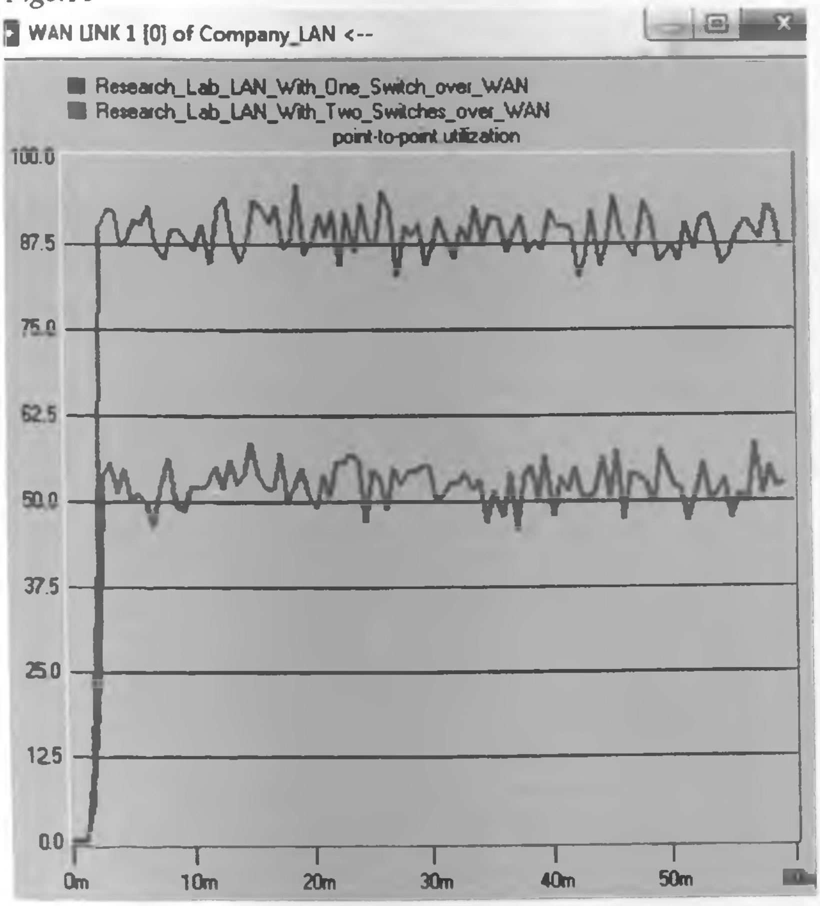


Fig 5.10 shows that LAN is segmented into 2, each having a switch & connected to Internet via 2 T1 lines.

EIGRP is used to perform Load Balancing on the 2 WAN links using the uniform distribution of variables to the simulation. EIGRP send the initial "hello" messages in discrete uniform distribution whereby a finite number of equally spaced values are likely to be observed; every one of *n* values has equal probability ***1/n***

What is compared in the 2 WAN link Utilizations, FTP Download & Web Response Times for a busy hour of the day.

The results are the WAN link utilization goes down from **87.5%** to about **50 %** by introducing LAN link.

Fig 5.11

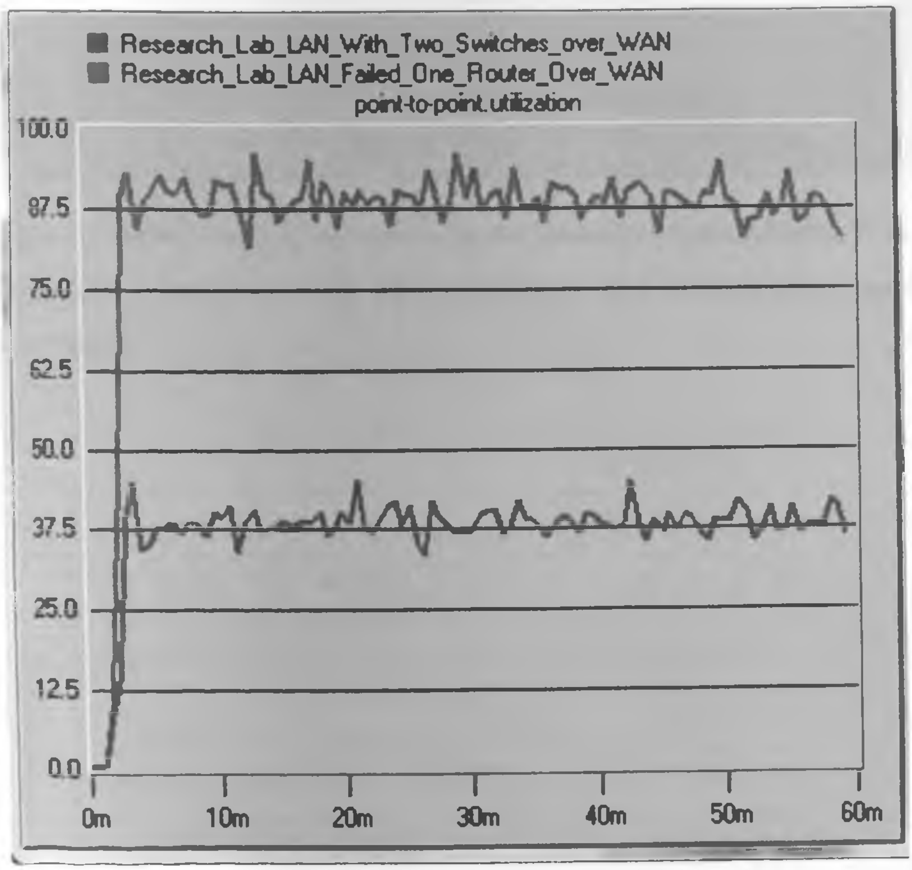


Fig 5.11 Shows the comparison of a simulated experiment in the research lab where two switches are used over WAN versus research lab with a failed router over WAN.

Fig. 5.12

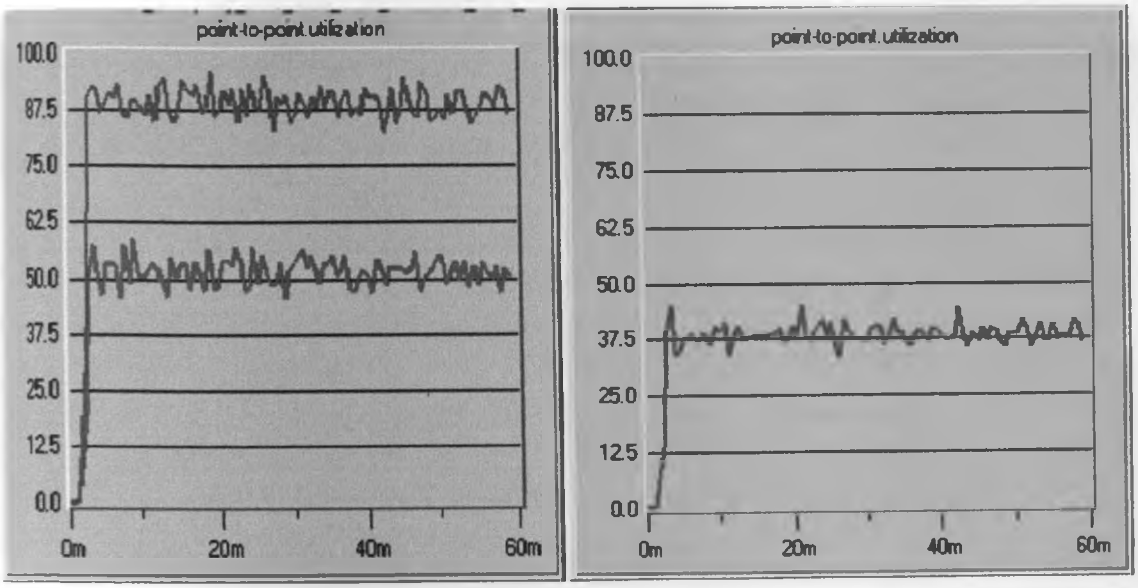


Fig 5.12 shows the link utilization for the lower link reduced from 92% to 55% and the new link utilization is close to 37%. Thus, enhanced load balancing has been done utilizing uniform distribution.

Fig. 5.13

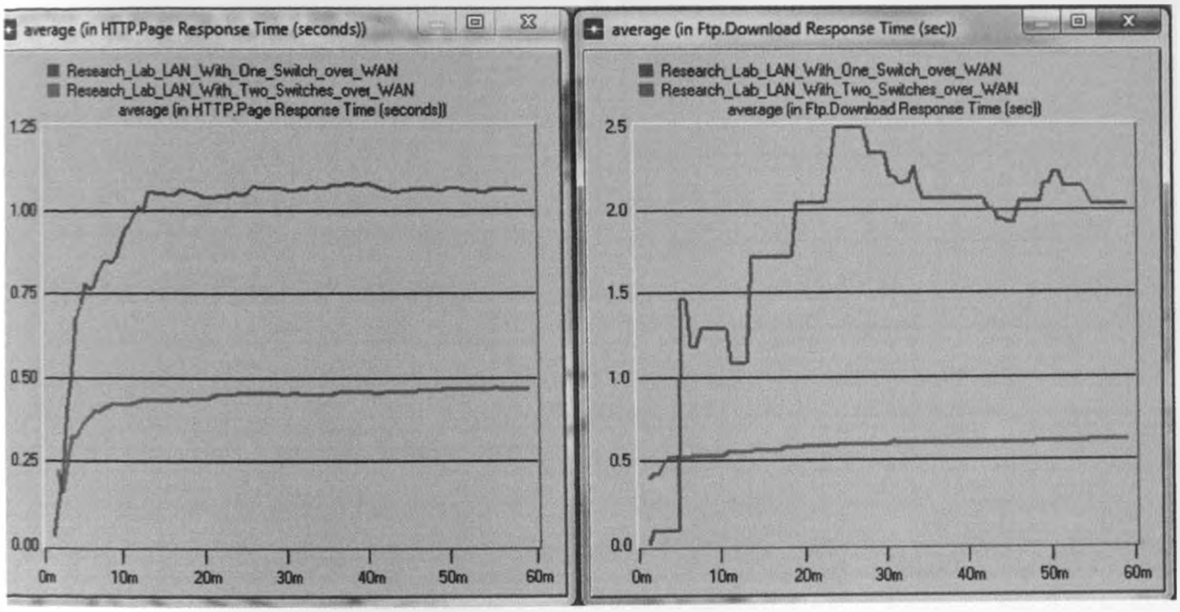


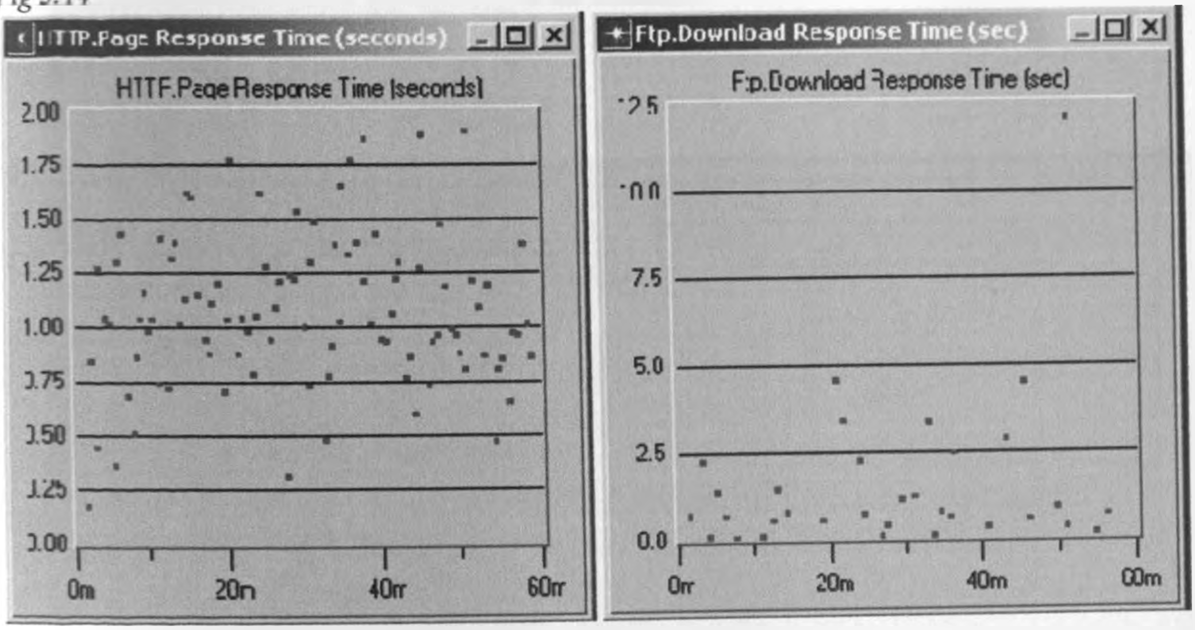
Fig 5.13 shows HTTP and FTP download response time (seconds) in the research lab with one switch over WAN and two switches over WAN.

Findings:

As expected, the link utilization for the lower link reduced from 92% to 55% and the new link utilization is close to 48%. Thus, load balancing has been done.

- Web Application Response Time went down from about 1.1 seconds to 0.45 seconds.
- FTP Download Response Time went down from 1.25 seconds to 0.6 seconds.
- This is a significant improvement in both, link utilizations and response time

Fig 5.14



The results are as shown on the graphs above.

- **Download link utilization** averages **92%.**
- **Web Application Response Time** is close to **1.3 seconds.**
- **FTP Download Response Time** is close to **2.5 seconds.**

With such high download link utilization; this does not give much available. bandwidth for potential user applications.

The results:

Fig 5.15

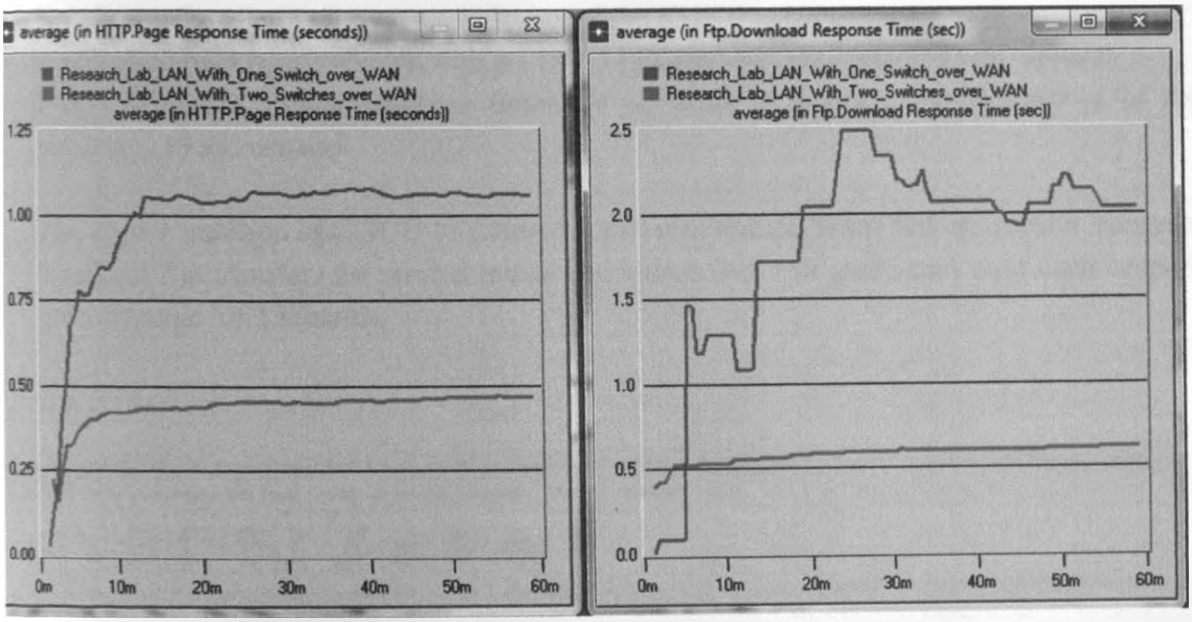


Fig 5.15 shows a comparison on the link utilizations, Web Application and FTP Download Response Times. The expectation is that the additional link to the ISP should reduce the application response times. The two links should also split the link utilizations.

Findings:

As expected, the link utilization for the lower link reduced from **92%** to **55%** and the new link utilization is close to **48%.** Thus, load balancing has been done.

- Web Application Response Time went down from about **1.1** seconds to **0.45** seconds.
- FTP Download Response Time went down from **1.25** seconds to **0.6** seconds.

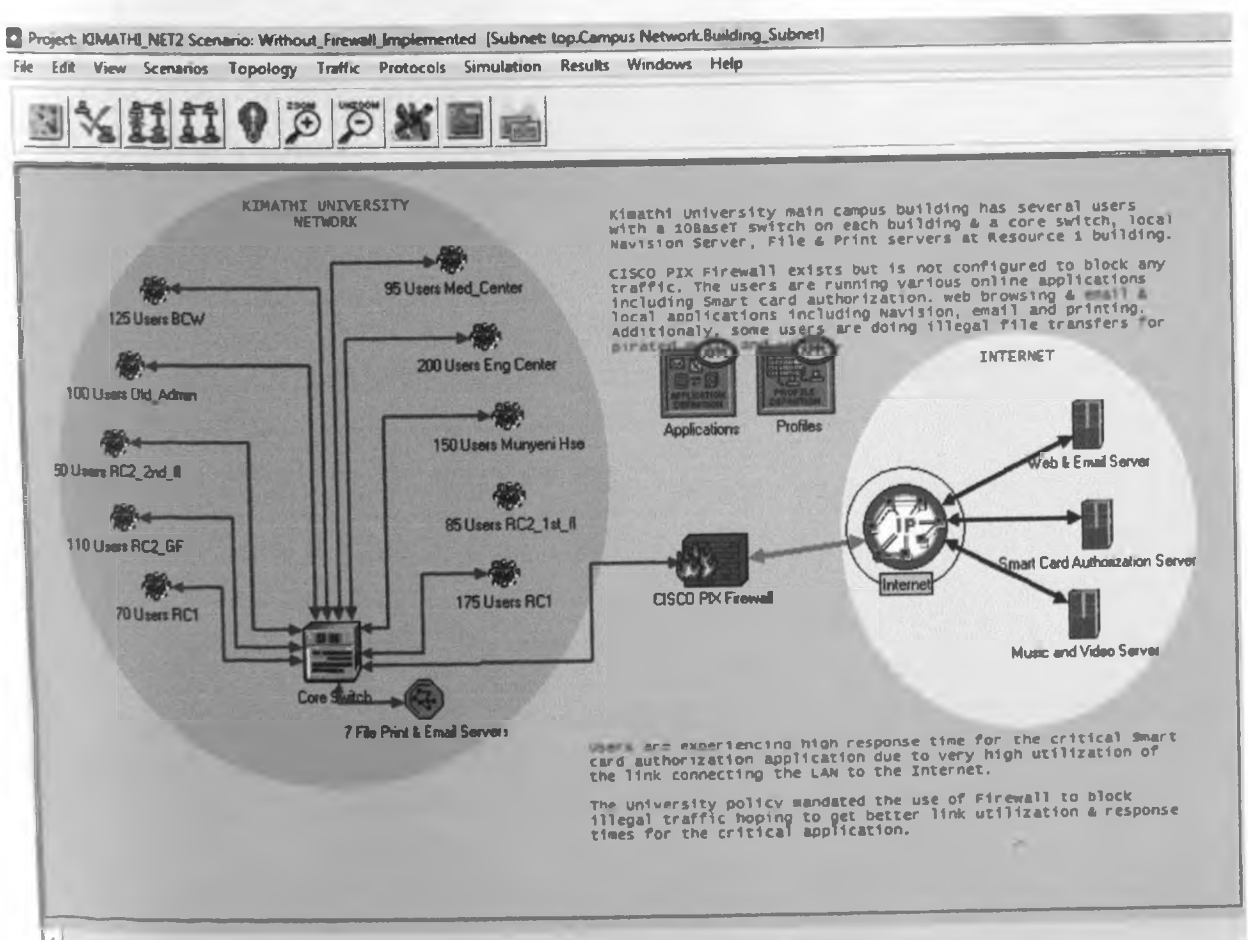
This is a significant improvement in both, link utilizations and response times.

Suggested Network

After all the experiments and simulations of the existing network system, some bottlenecks have been identified in the network design of the KUCT network which is daisy chain.
A collapsed backbone network with a CISCO PIX firewall implemented will be ideal.
This will ensure similar response times for all users in the network irrespective of their placement in the network.

The implementation of CISCO PIX firewall will also reduce WAN link utilization congested by illegal file transfers for pirated music and videos this will give smart card users response time average of **2 seconds.**

Fig 5.16



g *6.1* shows all users hooked onto the main core switch which to provide similar response ross the whole university. The CISCO PIX firewall is also featured in the suggested redesigned twork.

The research LAN lab has **downlink utilization** averaging to **92 %, web application sponse time** is **1.3 Seconds** and FTP **download response time** is **2.5 Seconds.**
is has beaten the logic for it to be a high bandwidth LAN lab.
ad balancing can be introduced segmenting the LAN into 2, each having a switch and router a 2 T1 lines. EIGRP will be used to perform load balancing. EIGRP (Enhanced Interior ateway Routing Protocol) is a network protocol that lets routers exchange information more ficiently than with earlier network protocols and Using EIGRP, a router keeps a copy of its eighbor's routing tables.

Fig 5.17

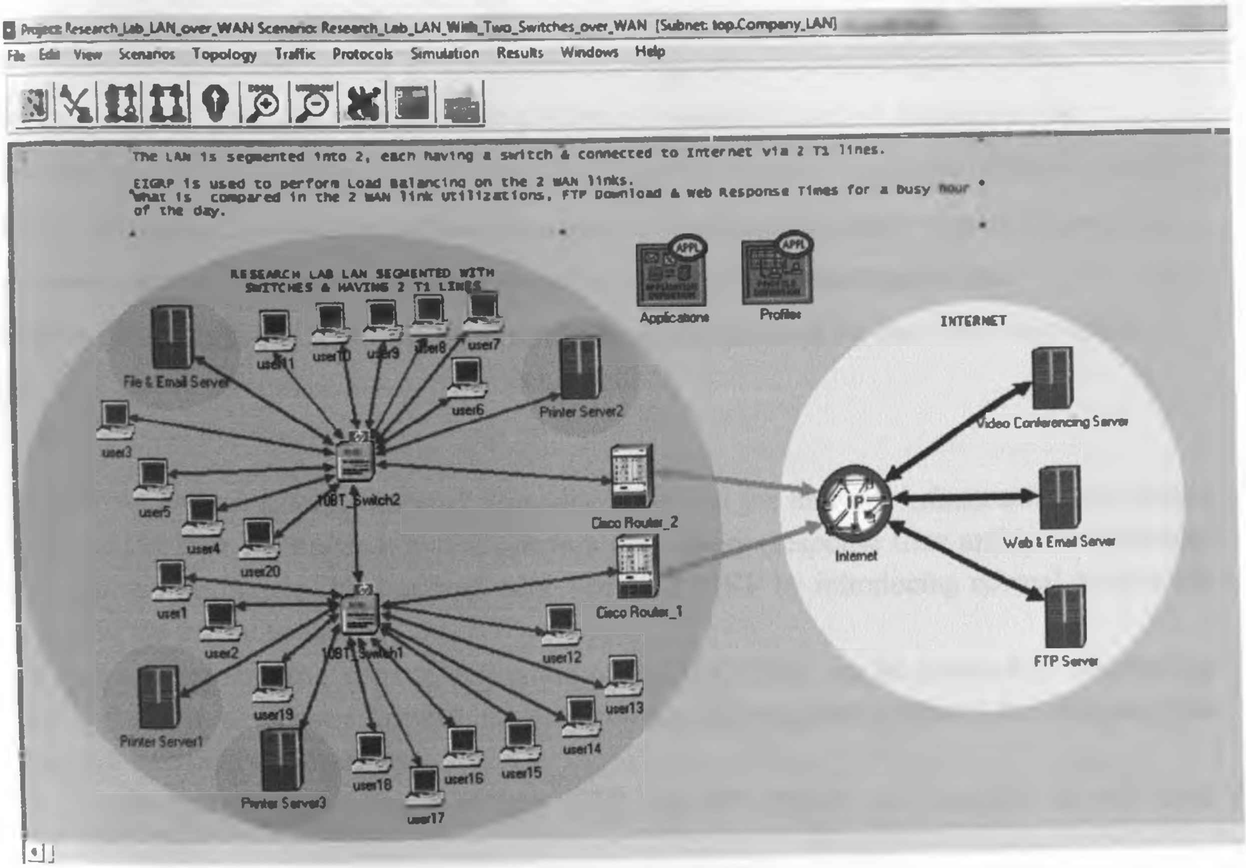


Fig 6.2 shows the suggested LAN segmented into two with two separate switches and two routers thus introducing load balancing using EIGRP.

EIGRP send the initial "hello" messages in discrete uniform distribution whereby a finite number of equally spaced values are likely to be observed; every one of ***n*** values has equal probability ***1/n***

CHAPTER 6: CONCLUSION AND FURTHER WORK

What we set out to do has been achieved through network simulation. We have developed a model for increasing network efficiency (response time and enhanced load balancing) by utilizing uniform distribution KUCT should adapt the suggested network which will help them serve in better and efficient manner in the sense that better response time in all users when querying the application, browsing and any other network related task.

The project has achieved the following in relation to the objectives set out at the very initial stage:

- To exploit an existing network simulation tool and the network infrastructure to develop a model that illustrates how the network parameters (response time and load balancing) can be optimized. This has been achieved via EIGRP by introducing normal distribution over the said interface.
- To determine if the average utilization of the WAN link can be reduced by configuring firewall. In response a firewall has been configured and greatly reduced the response time of the critical applications.
- To determine if the response time (FTP and HTTP) can be enhanced through load balancing.

This simulation focused on networks and Internet (the physical layer through the transport layer). However, application layer performance is of great importance to users. IT GURU Application Characterization Environment (ACE) module can help visualize, troubleshoot and predict application response times for the specific Microsoft Navision application which is the Enterprise Resource Planning (ERP) system of choice for KUCT. ACE will also predict application performance under varying configurations and network conditions. After using the ACE the university will have a holistic network environment with good performance.

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APPENDICES

Appendix A: User Guide

OPNET IT Guru Academic Edition

Introduction

OPNET IT Guru Academic Edition is a utility designed with educational purposes in mind, specifically to help users be introduced to the domain of networking.
Downloading, installation and activation procedures may appear to be lengthy and unusually complicated. One will need to make an account on www.opnet.com in order to receive a password that will allow a download process to be made and then, by the end of the installation procedure, the user will have to make a free license request.

The user can also develop his own projects by choosing a network scale, which can be as small as an office network or as large as a world-scale network, then choosing the model family (e.g., ATM, LANs, ethernet, Cisco, frame relay) and then making use of an object palette that includes items such as servers, routers, switches and others.

The utility is aimed at being used with appreciated networking manuals and it is helpful in learning how to design and analyze network models.

Prerequisites

System Requirements

Operating Systems:

- Windows NT 4.0

Service Pack 3, 5, or 6a;

Service Packs 4 and 6 are not supported

- Windows 2000
- Windows 7 Home or Premium

Service Packs 1, 2, and 4 are supported but not required

- Windows XP

Service Pack 1 or 2 is required

- Windows Vista

Service Pack 1 is required

Memory: 256MB required

Disk space: 200MB required (additional 200MB required during installation)

A minimum 20MB of additional disk space is also recommended to store model files created during labs and tutorials.

Display: 1024x768 or higher resolution, 256 or more colors

Downloading the software

If your computer meets the system requirements do the following :

1. Complete and submit the form.
2. You will get an email containing your username, password, and a link for downloading the software. Follow the instructions on the website for downloading the software.
3. Double-click on the file ITG_Academic_Edition_v1998.exe which you just downloaded.
4. Follow the on screen instructions to install.

Activating your software license

1. Click on Start/ Programs/OPNET IT Guru Academic Edition/ OPNET IT Guru Academic Edition. IT Guru Academic Edition will open up.
2. Select License/ License Management from the menu. Follow the onscreen instructions to activate your license.

Appendix C: The Design and Simulation Compilations

The design of the simulation, copy of the application and documentation is available on the project CD submitted.