CRITICAL STUDY OF BANDWIDTH MANAGEMENT STRATEGIES FOR INTERNET SERVICES [Case study Midlands State University]

By

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ABSTRACT

The internet has become a key resource at Midlands State University for research and communication. The institution is also experiencing high students' population which in turn has led to more demand for bandwidth. The high students' population makes the overall available bandwidth shrink leading to slow internet connection making internet an ineffective academic resource. The institution has been responding to slow internet connection by buying more bandwidth which is so uneconomical with bandwidth being an expensive resource. This work is an in depth survey on the causes of bandwidth problems, the basic models and techniques for bandwidth management and its followed by an analysis which is aimed at yielding meaningful suggestions on h on internet usage, educating the users on bandwidth management and looking into how to manage and optimize the bandwidth efficiently. The strategies were evaluated on traffic management, bandwidth allocation and bandwidth restriction. The findings obtained full proof that that traffic management, bandwidth allocation and bandwidth restriction can be used for effective bandwidth management. Suggestion for further research were given such as coming up with policies at the university on internet usage, educating users on bandwidth management and looking into Deep Packet Inspection.

Declaration

I ………………………………………….…..hereby declare that I am the sole author of this report. I authorise Midlands State University to lend this report to other institutions or individuals for the purpose of scholarly research.

Signature ……………………………………………. Date ……………..

Approval

This Project has been submitted with the approval of the following supervisor
……………………………………..

Signed …………………….	Date …………………

Dedication

This report is dedicated to the Almighty God and all my loved ones.

Acknowledgements

I would like to acknowledge my supervisor Dr. A Nechibvute for his guidance and advice, Mr Liberty Dandira for trusting me to carry out this project on Midlands State University's live network, my friend Nigel Mhasvi for loan of his laptop after mine was stolen.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background and motivation

The ever changing patterns in internet usage continue to generate resource and administrative challenges to network administrators [1]. Another major hurdle to bandwidth management is lack of technical skills by network administrators. This has been an issue since most bandwidth approaches will eventually require a technical implementation. From the information provided from MSU's IT department, over the past three years, MSU Gweru campus has been using a total bandwidth 967mbps. Of the total available bandwidth, the main campus has been allocated 750mbps and the remaining 217mbps was allocated to Graduate School of Commerce and Law. The main campus uses Powertel as its ISP and the school of law uses Liquid Telecoms as its ISP. It was learned that the main campus bandwidth is just evenly distributed, there is no distribution plan, same applies to the school of commerce and law. After buying more bandwidth in 2015 in response to the internet shortages at the university, the university has come to realize that if the problem is on managing bandwidth, then buying more bandwidth will not solve the problem at hand. Bandwidth management strategies need to be implemented.

1.2 Definition of terms

Bandwidth – this is the amount of traffic that a given link can transmit within a certain period of time [2].

Bandwidth management – this is the process of controlling traffic on a network link in an effort to avoid bandwidth wastage [3].

Adaptive bandwidth management – this is the process of allocating bandwidth based on the current needs of network users [2].

1.3 Problem Statement

Nowadays almost every endeavor of human daily lives depends primarily on computers and related devices which in turn are based on networks. Domestic, official, social, financial, economic, religious and academic have all become computer and network based. These activities when carried out with the computer have been proved to be more successful when computer network became involved. Computer networks require data bandwidth for its operation and functionality. Bandwidth is a very essential but expensive network resource which must be properly managed to provide the maximum require throughput expected by the network owners and network users. The lack of or improper management of a network to conserve bandwidth results to network failure or crisis.

The absence of bandwidth management strategies at MSU is resulting in network crisis and sometimes even network failure. It has become very usual for any educational group discussion not to end without mentioning internet unreliability. The university can't even carry out its business activities effectively and in time because services like online transactions are being delayed or even declined because of traffic congestion or what seems to be insufficient bandwidth, in the process losing so much time and money all being caused by lack of bandwidth management strategies.

1.4 Aim of the study

The study was undertaken to find ways to optimize and make efficient use of the available bandwidth at MSU, help the university in network planning so that the network stays up all the time.

1.5 Objectives

1. To provide good network performance and efficiency.

2. To limit non critical traffic in such a way that it does not affect necessary critical traffic.

3. To limit the size of bandwidth usage in a way to avoid waste.

4. To help plan on the network architecture based on the bandwidth utilization strategies.

1.6 Research Questions

1. What is the current status of internet connectivity at MSU that is leading to inefficient

usage of internet bandwidth?

2. What strategies of bandwidth management are used at MSU?
3. What challenges are MSU facing in an effort to manage internet bandwidth?
4. How effective are the proposed strategies in managing internet bandwidth for efficient utilization?

1.7 Significance of the study

This study is aimed at implementing efficient bandwidth management strategies for efficient utilization of internet bandwidth for MSU, and come up with solutions for problems faced in the process. The outcome of this critical study should help the institution(MSU) acknowledge that bandwidth is a valuable institutional resource that need to be properly managed, conserved and shared effectively through implementation of cost effective bandwidth management strategies, saving millions of dollars in the process. It is hoped that the results of this research study will make the institutions' responsible authorities realize that effective bandwidth usage will be greatly facilitated by the mere implementation of an institutional bandwidth management strategy. In addition, the findings of this research can be used as a strong foundation base for further research.

1.8 Organization of dissertation

This report comprises of five chapters, chapter one discusses how bandwidth management is done globally, aim of the study, objectives of the study and motivation of the study. Chapter two discusses various approaches of bandwidth management and implementation. Traffic management was discussed as the most convenient implementation approach for Midlands State University. Chapter three discusses evolutionary prototyping methodology which was used and implementation of the bandwidth management strategies on Midlands State University. Chapter four presents the results of the study. Chapter five presents the discussion and conclusions of the study.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this section, a brief and point by point study of various approaches that can be adopted in managing the scarce and limited allocated bandwidth are presented. Traditionally most routers treat packets on a shared network link, the traditional model allows users to transmit packets through the network without any limitations. This means that the performance of a network relies not only on the capacity of the link, but also on the amount of traffic each user puts into the network link. This means a single user running bandwidth intensive applications can consume a large portion of bandwidth, thus starving other users [1]. However [2] believe that the need for optimal usage and quality of service requires new methods of packet handling. According to [3] dynamic bandwidth management is proposed as an efficient technique. This technique adjusts bandwidth attached to a particular user over a time. This is done by monitoring user traffic patterns then allocating the available user traffic to accommodate this traffic. Dynamic bandwidth management scheme tracks users behavior over a long time and therefore the user cannot increase the bandwidth usage to a great extent over short time without hitting the upper bandwidth limit set by the allocation algorithm. In a dynamic management scheme, on one hand if the user requests for more bandwidth, the management scheme will associate more network resources with the user, on the other hand if the particular user reduces the amount of traffic he or she is using on long term basis, the algorithm will reduce the amount of network resources that had been associated with that user [3].

2.2 Network management and traffic control

2.2.1 The transmission control protocol

TCP is the backbone of the internet [4]. TCP provides a very reliable end to end connection for transmission of traffic irrespective of the status of the medium used in the network, making TCP connection oriented. This makes TCP a reliable protocol since any data transmitted is delivered accurately, error free and in the correct sequence. The packet sequencing of the packets is simply achieved by assigning a sequence number to each packet. These assigned sequence number enable the destination node to accurately rearrange out of sequence packets. TCP has also a number of features that assist in bandwidth management such as flow control and congestion control [4].

2.2.2 TCP congestion control

TCP being a connection oriented protocol there is always a connection between the source and destination nodes. The destination node send acknowledgement packets to the source indicating packets reception and the time taken to reach the desired destination. If the source happens to not receive the acknowledgement packets after transmitting it subsequently assumes that the link somehow is congested and therefore ceases to transmit or send data. Essentially this leads to reduction of the data being transmitted. Traffic shaping techniques can take advantage of this by deliberately dropping packets which in turn makes the transmitting node to drop its transmission rate easing congestion in the network [5].

2.2.3 TCP flow control

TCP implements flow control through feedback based control and, rate based flow control. In feedback flow control, a destination node sends information to the source node, permitting it to continue sending or informing the source node on how it is coping up with the traffic. In rate based flow control, TCP limits the rate at which the source can continue sending data. This however does not require any feedback from the destination. Both these methods lead to the reduction of the source node data rate either to the rate at which the destination node processes its packet or to a rate set by the dedicated sending protocol. This flow control mechanism ensures that the end devices are not overwhelmed by packets. However TCP does not have the capability to distinguish between services, interfaces and protocols. This limitation makes TCP not to be useful in bandwidth management technologies [8].

2.2.4 TCP congestion avoidance mechanisms.

In a network when congestion is detected, TCP reduces the transmission rate. This is achieved by congestion avoidance algorithms on the nodes interface that drop packets causing the TCP to retransmit at a slower speed by use of sliding window control protocol. The sliding window protocol is a flow control technique that tries to reduce congestion by matching the speed of the sender to the speed of the receiver. This however ensures that the sender does not overwhelm the receivers with data. TCP uses the sliding window protocol (SWP) to detect signs of congestion before it happens by increasing/reducing the load being experienced by the network accordingly. The SWP achieves flow control by receiver sending a window back to the sender. The size of the window however informs the sender of how much data to send. If the receiving end node fails to send a window, the sender will interpret this as a sign of congestion and in response it reduces the rate of transmission. SWP also uses the speed at which all acknowledgements are sent from the receiver to gauge the level of network load and adjust the amount of data to be sent accordingly. The sliding window protocol specifies a congestion window which is derived from the rate at which the source receives acknowledgment packets [4]. However [6] describes this derivation in two stages, the first stage being known as slow start, where the source begins by setting the congestion window to one or two packets. The source then increments the window by one each time an acknowledgement is received, eventually doubling the window every round. This process continues until the packet loss is detected. At this point, the source jumps to the second stage. At congestion avoidance stage, TCP uses two algorithms: one of the algorithms is random early detection which drops packets from any outgoing traffic flows at random when the interface buffer fills to capacity. This ensures that all TCP flows that pass through the interface will reduce in speed. This characteristic of TCP maintains equity in the traffic that is discarded [7]. The second algorithm that is used by TCP at congestion stage is called weighted random early detection (WRED). WRED implements weights when it comes into dropping packets. RED uses RED to discard packets but assigns weights to each flow so that more or less packets can be dropped from a particular flow, which then makes it possible to specify a particular transmission rate of transmission for that flow.

2.2.5 The user datagram protocol (UDP)

UDP permits data to be sent without any connection established thus making UDP a connectionless protocol. In UDP data is encapsulated in a datagram then it is sent to the destination without any concern whether the destination is ready or not. UDP offers the best effort delivery of datagrams. Since acknowledgements are not sent to the transmitting node, there is no likelihood of retransmission in the instance that datagrams are dropped by any of the intermediate nodes. In addition the user datagram protocol header does not comprise of a sequence number, therefore the destination node does not have any way of knowing the order in which the received packets are supposed to be. This makes UDP more suitable for transmissions which do not require quality of service but less appropriate for connections that require quality of service [9].

2.3 Bandwidth usage optimization

According to [10] there are three methods of optimizing LAN bandwidth, these include traffic management, caching and compression.

2.3.1 Traffic management

Traffic management is considered as the ability of a network to ensure network fairness in the network by guaranteeing that all the network users at least receive a given amount of bandwidth [10]. To ensure a user in the network does not receive more or less bandwidth, a traffic management solution must have user awareness [10]. However the traffic management solution must also be able to monitor or control all inbound and outbound traffic. Particularly, inbound traffic should be managed more since most of the bottlenecks usually occur here. Scheduling and queueing mechanisms provide much control over traffic leaving the network but do not really address incoming traffic in the network. Technologies like TCP are more advantageous as they provide bidirectional management of traffic through the use of acknowledgements. Traffic management is very essential in optimizing local area network bandwidth, although caching and compression techniques provide additional benefits, but without traffic management their effectiveness would be greatly reduced [9].

2.3.2 Caching

Caching is used to accelerate delivery of content as well as to optimize the use of available

bandwidth. Caching can however be implemented in so many various ways. Browsers of a local cache for the recent accessed Web Pages' proxy cache which is implemented at the LAN edge and processes requests from many users. A datacenter cache is useful in trying to offload servers and helping to speed the data access out of the data center. Proxy caches are the most favorable when it comes to management of the bandwidth [11]. Even though caching is advantageous in the acceleration of information retrieval from the internet, it is only suitable for services that do not really deal with real time data [11]. Despite conserving the internet bandwidth by inspecting all logs produced by server (proxy) a system administrator is also able to view and establish network usage behavior [11]. When properly implemented, caching can have significant impact on bandwidth usage even without implementing other bandwidth management tools. However in order for caching to be so effective it needs to be implemented throughout the organization.

2.3.3 Compression

Compression is a bandwidth management technique that is used to reduce the size of a file data to be transmitted through a network. In particular compression can make the network perform as if bandwidth has been increased [11]. While there are cases where compression can be effective in optimizing bandwidth usage, [11] there are cases where it is problematic or does not provide any value. For instance when a central site is communicating with a quite a number of remote sites, compression does not really offer any significant value in terms of memory and CPU usage. This however is because with increase in remote connections it effects in CPU utilization in compression which increases latency. In addition to that, compression also offers little value to certain types of traffic such as VOIP. VOIP traffic is already compressed thus it cannot be compressed any further. Conclusively, since a fully effective bandwidth management solution need to address both throughput and latency concerns, compression happens to only address throughput but increases latency therefore can not be used alone.

Table 2.1 Comparing bandwidth optimization techniques

	Traffic management	Caching	Compression
Protect mission critical applications	YES	NO	NO
Reduce bandwidth	NO	YES	YES
Optimize bandwidth	YES	NO	NO
Core or edge deployment	Core or Edge	Edge	Core and Edge
Cost of deploying	Variable	High	High

2.4 Bandwidth Control and the Hierarchical Network Model.

The internet is based or deployed on a layered architecture in which each layer carries out or implements a different functionality. The OSI model developed by the international standard organization as a reference model for network layered architecture. The OSI model constitutes of seven layers while internet model constitutes of only four layers. The physical connections e.g. the wires are located at layer 1 while the user is located at the OSI layer7 [12]. According to [13] traffic management can be applied at any layer. Access control is however implemented at internet transport and application layers. For example the integrated services protocol is found at the transport layer. Traffic shaping is implemented at any internet layer for example the TCP protocol at the transport layer, and the differentiated services at the network layer. Practices that utilizes deep packet inspection by virtue utilize multiple layers. Bandwidth management techniques can however be implemented at either at the end points (e.g. in a personal computer) or at the transit points (e.g. network routers). Personal computers implement all the seven layers with the network interface card implementing OSI layers 1 and 2, the operating system (e.g. windows) implements OSI layer 3 and part of layer 4 through 7 and application software's implements layers 4 through 7 [12].The network router contains layers one through three. However [14] suggests that network functionality should be implemented in OSI layers 1 through 3 only if it cannot be implemented efficiently in higher layers.

2.5 Bandwidth management techniques

2.5.1 Queuing and scheduling techniques

Scheduling mechanisms employ various and different actions on packets of data in providing different levels of service. These mechanisms are mainly meant for controlling the transmission of packets and they are considered to have great impact on quality of service through determining the sequence in which data packets from all different flows are processed. These mechanisms are also used to ensure that all packets are handled in a fair manner to prevent one user from utilizing more than his or her share of resources [1].

FIFO

In this mechanism or approach the first packet in the queue is the one which is served first. In a FIFO queue all packets are treated the same. In this mechanism if a queue becomes too congested the incoming packets are dropped. The main advantage of FIFO queueing is that it is simple and considered as a good solution for dealing with software based routers. In the instance that there is no congestion in the queue, the resource allocation in the network is quickly done because of simplicity of the technique. However FIFO does not provide any means of packet handling when the packets are in different categories. To add on, queuing delay increases with increase in congestion which in turn affects queued packets. More over during network congestion FIFO benefits non connection oriented flows such as UDP over connection oriented flows such as TCP. It is so because if a TCP packet is lost, TCP will understand that the queue is full and it therefore reduces the number of packets being sent. In contrast to that, if a UDP packet is lost, it does not affect transmission as UDP will continue to send packets normally. This however leads to unfair network resource allocation between TCP and UDP flows. FIFO is effective in situations where the number of packets is less than the capacity of the queue this is because in a case where there are excess packets these packets are discarded [3]

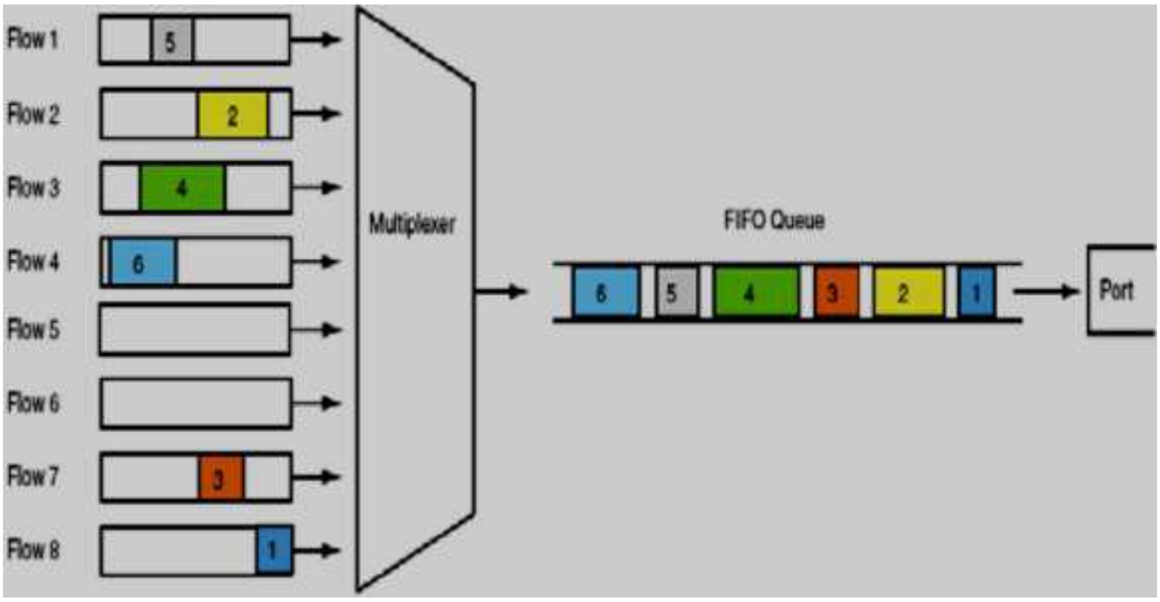

Fig 2.1 First-In-First-Out (FIFO) queuing [1]

Priority queuing

Priority queuing is considered as one of the most elemental forms of scheduling mechanisms due to the fact that it allows fixed number of queues needing or requiring different priorities. This technique provides differentiated services for different levels of queues, with high priority queues being the ones to be served first. If high priority queues are not occupied, packets are then scheduled in low priority queues. If low priority queues are congested packets are dropped. The figure below illustrates priority queueing. In this case flow number 3 is classified under high priority while 2 and 7 are classified as middle priority, and all the other flows are all classified as low priority queues. Packets classified under high priority queue are scheduled in a FIFO order. Only when the high priority queue packets are served and the queue is empty, that the remaining queues are served [2]. However [13] observed that the main advantage of this queuing mechanism is that it is simple and different classes of traffic are handled in different ways. The down fall of this technique is that if the amount of traffic in the high priority queues is too much, the low priority queues would suffer from resource starvation [13]. It is for this reason that priority queuing is not best employed in end to end service guarantees. To avoid starvation, [3] propose that the amount of traffic to the high priority queues should be limited using proper admission control policies. Priority queuing can however be combined with a rate meter such as leaky bucket so as to ensure that higher priority queues do not monopolize the link.

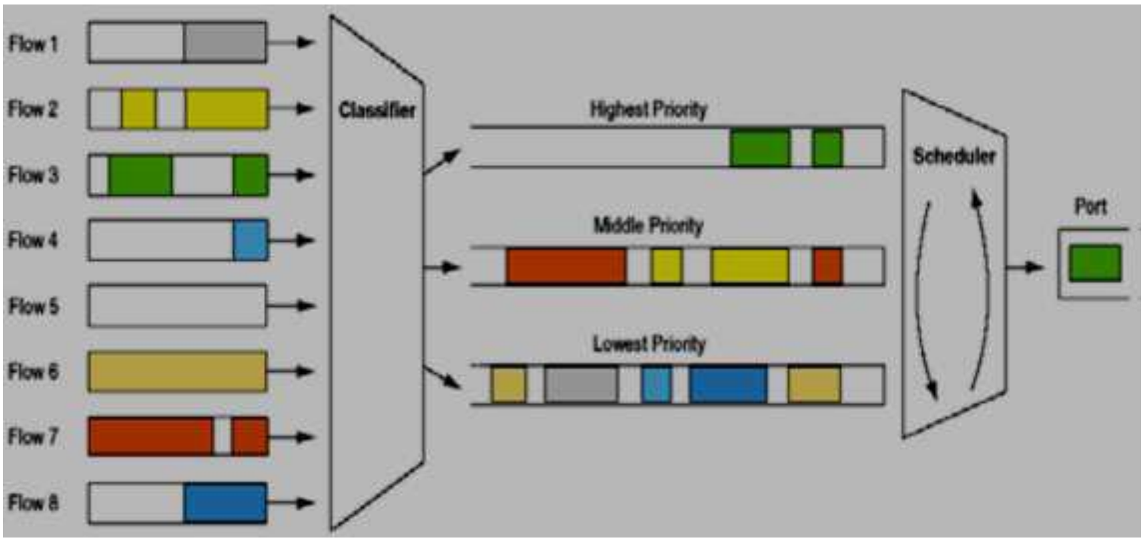

Fig 2.2 Priority Queuing (PQ) [1]

Fair queuing

In a fair queuing scheme all incoming packets are classified into different flows and are then stored in a queue which is dedicated to only that particular flow. In this scheme a round robin algorithm is implemented so as to allocate the network resources, ensuring that one source does not consume the whole bandwidth. The main advantage of using this scheme is that in the instance that a flow becomes too busty only its queue is affected and does not affect the overall network performance. The downfall of this fair queueing technique is that it does not take into account packet length and therefore in the instance that a queue contains larger packets than others then that queue will consume more bandwidth and will also take longer to be served. Fair queuing is useful in sharing bandwidth among many flows but it is not useful for handling different flows of bandwidth requirements [14].

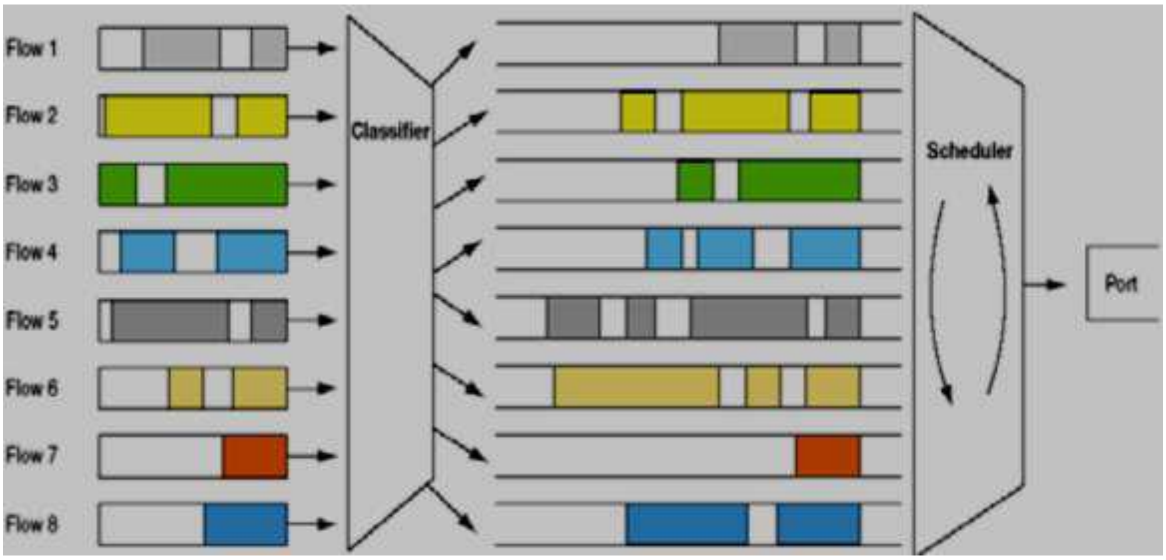

Fig 2.3 Fair Queuing (FQ) [1]

Weighted fair queuing

The weighted fair queuing technique employs a combination of both priority queuing and fair queuing. In this technique all queues are served in a way that there is no bandwidth starvation, however the weight of the queue determines the amount of the service it will get. Different weights are attached to various queues and the packets are stored in the appropriate queue in accordance to their classification. Fig 4.6 below illustrates the so called weighted fair queuing algorithim. Initially packets are handed over to the scheduler. The first queue (queue 1) has a weight of 50%, 2 and 3 have 25% each. As illustrated in the diagram, the first two queue 1 packets gets the finish o completion time of 30 and 40 respectively; and are therefore forwarded before the packets in queue 2 with a finish time of 70. The main advantage of weighted fair queuing implementation is that it allocates a minimal level of bandwidth or bandwidth level to each configured class .On the negative side weighted fair queuing is not suitable for situations with high volume of traffic requiring many classes of service.[9]

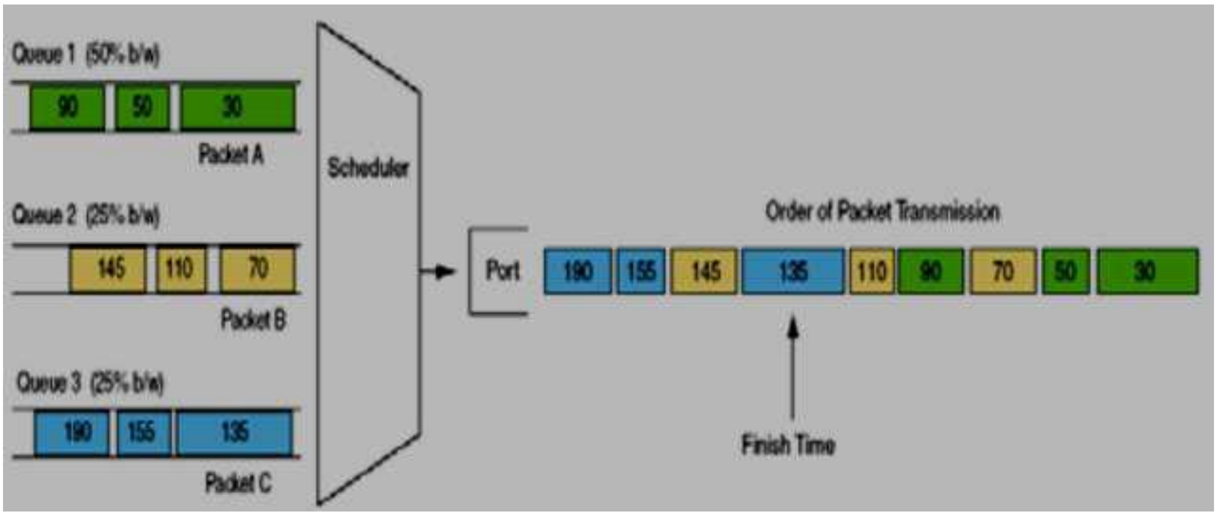

Fig 2.4 Weighted Fair Queuing [1]

Class based queuing

In this scheme packets are put in queues guaranteeing a certain transmission rate .If a given queue has no packets; its bandwidth is given or allocated to other queues. Therefore the mechanism enables the whole network to cope up with flows which have considerably different bandwidth requirements by allocating a specific percentage of the link bandwidth to each queue. The focal strength of this class based queuing scheme is that no queue experience bandwidth starvation, since each class happens to receive a specified amount of service per each round. Class based queuing can also be used to control and monitor the amount of bandwidth that each service class can actually use and it is implemented easily in hardware. The downside of CBQ is that it only provides fair allocation if all the packets are of the same size [9]. If it happens that other queues contain larger packets than others they end up utilizing the whole bandwidth. Also in an effort to provide fairness, CBQ does not provide strict priority to the deserving traffic [9]

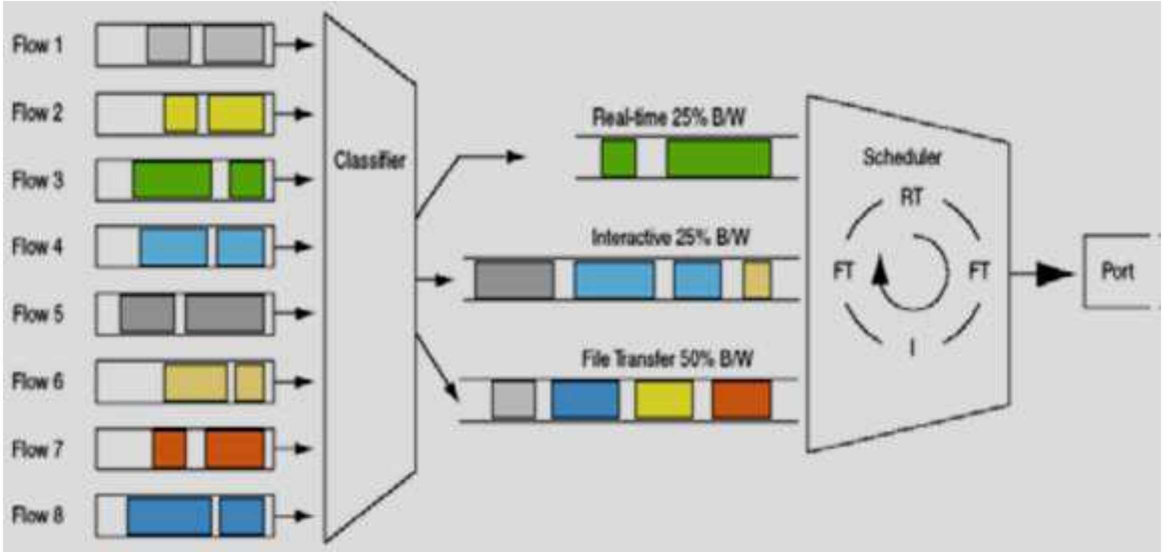

Fig 2.5 Class-based queuing (CBQ) [1]

According to [1] the main downfall of packet scheduling as being that it is difficult to implement prioritization. This is due to the fact that as a general principle of packet scheduling it demands that for all packets the average waiting time does not change or vary under different schedules. This is because by giving priority to a packet for earlier transmission comes at an expense of other packets as they will have wait longer for them to be transmitted. Prioritizing one packet flow comes at an expense of other packets. This makes fairness a big issue when packet schedules are considered. Despite this drawback packet scheduling techniques are easier to implement [1].

2.6 Admission control and traffic shaping techniques

This mechanism first checks whether there are enough resources available to serve new traffic, if the network resources are available, the packets are admitted to flow in the network [1]. This is done so as to prevent network overload. If the admission control technique is not employed, it is so difficult to provide non identical service classes effectively because it is impossible to prevent a class from using more than maximum amount of the network resources that will be reserved for that class. In the admission control mechanism packets are classified and then the admission filter checks on whether there are adequate resources according to the particular service classification in question. Admission control enforces use of network resources based on a certain policy. One of the various techniques employed in admission control is capacity based admission control which examines how flows are admitted until capacity is exhausted (first come first admitted) without any additional check. New flows are not permitted until there are enough network resources available. Another admission control technique allows flows to preempt others according to its specific priority settings. This method provides the advantage of efficient service as the amount of resources used by low priority traffic is controlled [15]**.** However [16] believe that increasing high priority traffic can affect the performance of lower priority traffic therefore good control algorithms should be employed. After traffic has been successfully admitted via admission control techniques in the network, traffic shaping techniques are then used to control volume of the traffic entering the network. This ensures packet flow is smoothed based on the traffic load configured on the network. Traffic shaping is implemented using a leaky bucket filter and token bucket techniques [15]**.** Traffic shaping can be done at the end systems or in the network by the switch hardware. At the end of systems it can be implemented by servers using a leaky bucket (single or dual shaper) consisting of a buffer and rate control mechanism, shaper delay and delay variation and the shaper buffer size at the server. The rate controller is the one that determines the outgoing data rate which however should be consistent with the available bandwidth in the network.

The Close loop feedback rate control utilizes the feedback obtained from the network in controlling traffic rate. The traffic shaper require a large buffer so as to accumulate the incoming stacked stream. Traffic shaping controls data transfer rate. Data transfer rate can also be limited to a derived rate or specific configured rate based on the level of traffic congestion. The transfer rate depends on burst size, measurement interval and mean rate. This mean rate is equal to the burst size divided by measurement interval.

When traffic shaping is implemented the interface bit rate will not exceed mean rate at any given time. This implies that during each interval maximum burst size may be transmitted. Traffic shaping smoothens traffic by storing traffic above the configured rate in a queue. In a traffic shaping scheme when packets arrive at the interface for transmission the following takes place; if the queue is empty, the arriving packets are processed by the traffic shaper. If possible the traffic shaper will then send the packet. Otherwise the packet is queued. When the packet arrives and the queue is not empty, the packet is then placed in the queue. If there are packets already in the queue, the traffic shaper will remove the number of packets it can only transmit from the queues in every time ***t*** interval.

2.6.1 Leaky bucket

In the implementation of the leaky bucket algorithm, each host is connected to the network by an interface containing a leaky bucket which is a finite internal queue. When a packet arrive at the queue, the leaky algorithm checks whether queue is full. If it finds the queue full packets are dropped. This implies that if more than one processes which is within the host tries to send a packet whilst there already is maximum number of packets queued, new packets are dropped. Any host in the network is allowed to place or put one packet onto the network during its allocated time.

When a packet arrives and the queue is not full, it is appended to the queue otherwise it is discarded. At any given time ***t***, one packet is transmitted unless there are no other packets to be transmitted. The algorithm utilizes a counter which is initialized to ***n***. If the current packet has a size which is less than the current value of n, it is transmitted and the counter is decremented by the number of bytes equal to the size of the packet. Additional packets may also be sent as long as the counter is high enough. This mechanism is used to smoothen out excess traffic. Excess chunks of traffic are stored in the bucket and sent at an average rate [17]. According to [17] the leaky bucket algorithm is most effective in situations where there is a need to enforce a constant transmission rate in a network. This is very useful if the purpose for bandwidth management is only to ensure that traffic is flowing at a constant rate. However [16] identify this as a weakness since most of the internet applications are bursty in nature and enforcing an average rate would deteriorate network performance.

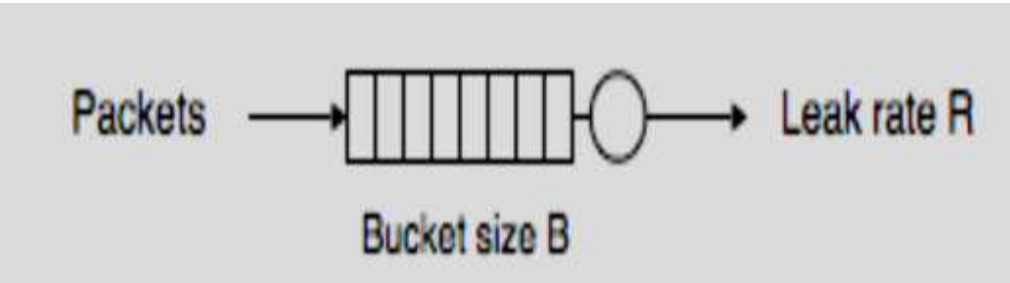

Fig 2.6 Leaky bucket Algorithms [17]

2.6.2 Token bucket

This technique controls traffic by use of tokens. A token is generated at a rate of one token every **T** time units, and then these tokens are stored in token pool of finite size **S**. In the instance that the token pool is full, additional tokens are discarded. For a packet to be transmitted it must make use of a token from the token pool. If a packet finds the pool empty the token can then either wait for a new token to be generated or it is discarded. The token bucket algorithm saves up tokens during idle times which are used later when there are no tokens in the bucket. This optimizes the speed of the network if N packets meet N tokens. But it can also cause congestion if the traffic gets too busty [17]

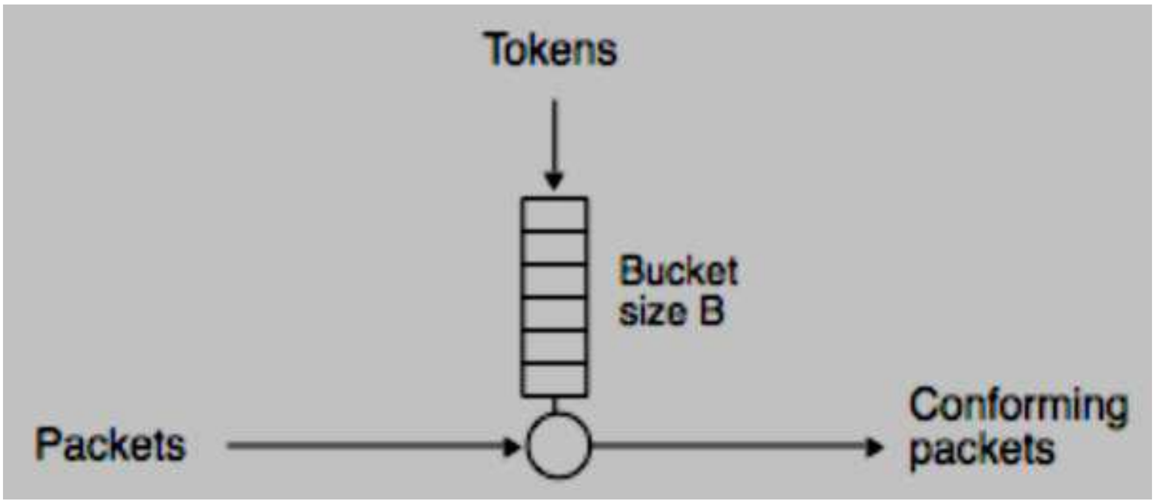

Fig 2.7 Token Bucket Algorithm [17]

2.7 Bandwidth Management Implementation Tools

2.7.1 Cisco routers

Cisco systems all have an operating system called IOS which can be configured for bandwidth management tasks. The Cisco IOS supports two kinds of bandwidth management mechanisms shaping and policing [18].

Cisco Generic traffic shaping (GTS)

This is a default shaping method which is found on Cisco routers. It makes use of the token bucket algorithm in the smoothening of outgoing traffic to a specific bit rate. GTS is implemented in a particular interface and it uses access control lists to select traffic to shape. GTS can be configured on a frame relay sub interface for dynamic bandwidth allocation. In this particular case, GTS uses backward explicit congestion notification or shaping traffic to a specified rate [18]. GTS uses weighted fair queuing (WFQ) for outgoing packets [18].

Cisco Class based shaping

This shaping method applies generic traffic shaping on a particular class of traffic. In class based shaping, GTS utilizes classes which increases the flexibility in configuration. CBS however supports class based weighted fair queuing as its mechanism for queuing outgoing packets. A maximum of 64 classes can be configured in CBS as well as bandwidth assignment for each particular class [18]. Peak and average traffic shaping rates can be configured for each particular interface or class. This implies that bandwidth can be allocated more effectively as it provides more data to be sent if bandwidth is available [18]

2.7.2 Linux

Linux is an open source operating system that ca n be configured in a network on a server client computer for bandwidth management, [19] points out that since Linux kernel contains the ability to manage and control networking traffic using the tc command and with the correct configurations Linux can be used to implement traffic shaping for bandwidth management. The tc command controls traffic leaving a certain interface through traffic shaping. For controlling incoming traffic to a certain interface, the tc command implements a process known as ingress policing. Tc command implements policing by the use of a buffer less token filter which implies in a case when packet arrival rate is more than the token bucket configurations packets are dropped. For packets sequencing and queuing tc supports techniques such as priority queuing, FIFO, token bucket filter and Schotastic fair queuing. To implement bandwidth sharing, tc utilizes the class based queuing and the hierarchical token bucket. In addition tc uses the inbuilt u32 classifier or the Linux IP tables firewall package [19].

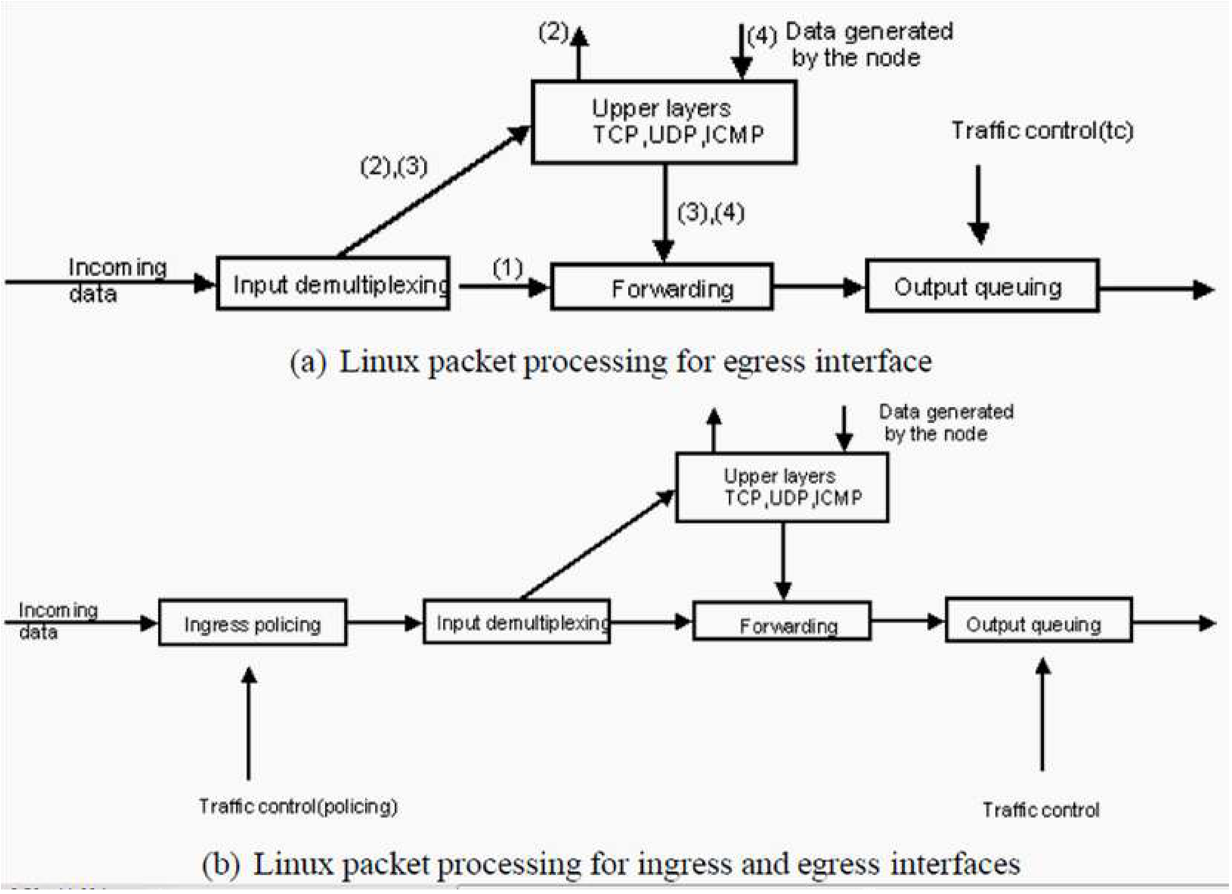

Fig 2.8 Linux Packet processing [19]

Squid Linux

Squid Linux utilizes proxing and caching features for traffic management. In addition, for squid to support bandwidth management, it uses delay pools for bandwidth management by limiting the bandwidth for a particular group of users. Squid delay pools employ the token bucket algorithm for allocation of bandwidth to users connected to the internet. Each configured pool has its maximum and restore value. The maximum value indicates the maximum token bucket size while the restore value indicates the rate at which tokens are replaced into the bucket. Squid keeps log files of all sites visited which can be used by network administrators to determine bandwidth for a particular user or group of users [20].

2.8 Bandwidth management and optimization trends

With bandwidth being a scarce and valuable resource in any network, efficient bandwidth utilization plays an important role in ensuring good network performance in an organization,

[21] believe that with constant developments in networks and network technologies, bandwidth management techniques also have to evolve to remain effective. Unified Bandwidth Management (UBM) is a relatively new bandwidth management technique in the industry. UBM provides network administrators with a unified platform to optimize network performance, which improves productivity and reduces telecommunication costs[10]. UBM appliances provide full application layer delivery services, and includes link/tunnel bonding, dynamic bandwidth management, automated network failover, local and geographic server failover and load balancing, network redundancy, packet/traffic shaping and optimization with real time network reporting. Many organizations are increasingly using UBM as an integrated approach to solve their bandwidth management problems.

2.9 Critique of the literature

The literature reviewed has explored various ways of optimizing bandwidth in a network. The literature is however limited to the TCP/IP model architecture and how bandwidth can be controlled using this architecture. The literature looked at various approaches to bandwidth management which include caching, compression and mainly traffic shaping.

Caching was found to be effective but it required to be implemented across the whole organization and sometimes it slows down the page retrieval process in the instance that the page or site that one wants to access is not saved in the cache but it has to pass through it still, delaying the process, while compression was found to require CPU utilization especially for all remote sites.

The literature uncovered that traffic management would be more effective but with integration of both caching and compressing where necessary and where possible. Packet scheduling techniques were found to be relatively easier to implement but on the other and they do not implement traffic prioritization effectively. Leaky bucket was found to be effective in environments where constant traffic flow rate is required. However establishing a constant flow rate is not technically feasible since most internet applications are busty in nature. Token bucket algorithm was also found to be effective so much in bandwidth optimization due to its special ability to preserve tokens during idle times, however the major challenge with it is it experiences congestion during peak working hours.

Traffic management and caching were the ones discussed more because they are the ones which are more relevant to this study. Section 2.7.1 looked at cisco routers and Linux operating system as examples of bandwidth management tools. Both of these approaches were found to be effective but cisco routers that one of the team members working with them should be a Cisco Certified Network Professional or should have been given hands on hands n experience by a CCNP which was not the case with the team working on this project. On the other hand Linux requires the system administrator to have excellent knowledge in Linux programming, which was not the case.

Traffic shaping and caching were the ones found relevant to this study. From this we gather that that the literature review mainly focuses and support the needs for this study.

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CHAPTER 3

METHODS OF EXPERIMENTAL TECHNIQUES

3.1 Proposed Method

To meet the objective of this study, which was to come up with and implement bandwidth management strategies for internet services at MSU, the study adopted evolutionary prototyping methodology. According to [1] evolutionary prototyping as a technique that acknowledges that we do not understand all requirements and builds only those that are well understood. The reason why this methodology was chosen is because it provides a platform for system development in an environment where the system requirements might change over time. Evolutionary prototyping methodology starts with collection of the requirements, then the system designed to fulfill these gathered requirements.

The system or strategies are then implemented, tested then used. However all these steps should ensure that there is requirement refining, design refining, re-implementation and re-testing. It has been realized that evolutionary prototyping is so effective in design and analysis of network management systems, for example that of bandwidth management.

Evolutionary prototyping allows users to continuously interact with the system being developed which in turn helps a lot in refining the requirements. In the case of bandwidth management strategies for efficient bandwidth utilization for MSU internet, the strategies would be deployed straight in a live network. The prototype would then be tested for efficient bandwidth management, based on the users feedback, the prototype would be re-designed or implemented as a final product [2]. A case study of was used because it enables a researcher to closely examine requirements within a specific context [3].

3.2 Tools employed

3.2.1 SNMP (Simple Network Management Protocol)

SNMP is a vial tool for effective network management. This protocol allows different devices of different hardware and software on nearly any manufacturer to communicate in real time [2]. In this case, since pfsense was to be used as the software firewall, it was required to communicate with the powertel router, cisco switches and many other switches hence SNMP was required to make enable all these network devices to communicate. Pfsense was required to communicate with the MRTG too, so for it to be able to communicate with other software packages SNMP had to be installed on a windows computer which Pfsense was installed.

3.2.2 Pfsense

Pfsense is an open source firewall computer software distribution based on Free BSD. It is the one which was used to implement traffic management and traffic shaping and scheduling in this project. Both ingress and egress traffic was controlled by this software firewall guaranteeing minimum bandwidth and prioritizing traffic based on access rules created in the firewall. The software was configured on a windows computer with the help of the IT team, and as mentioned above it was communicating to the other network hardware via SNMP. The screenshots of traffic shaping are shown below. Fig 3.1 simply illustrates the first stage in traffic shaping, which is just specifically selecting the traffic shaper on the firewall.

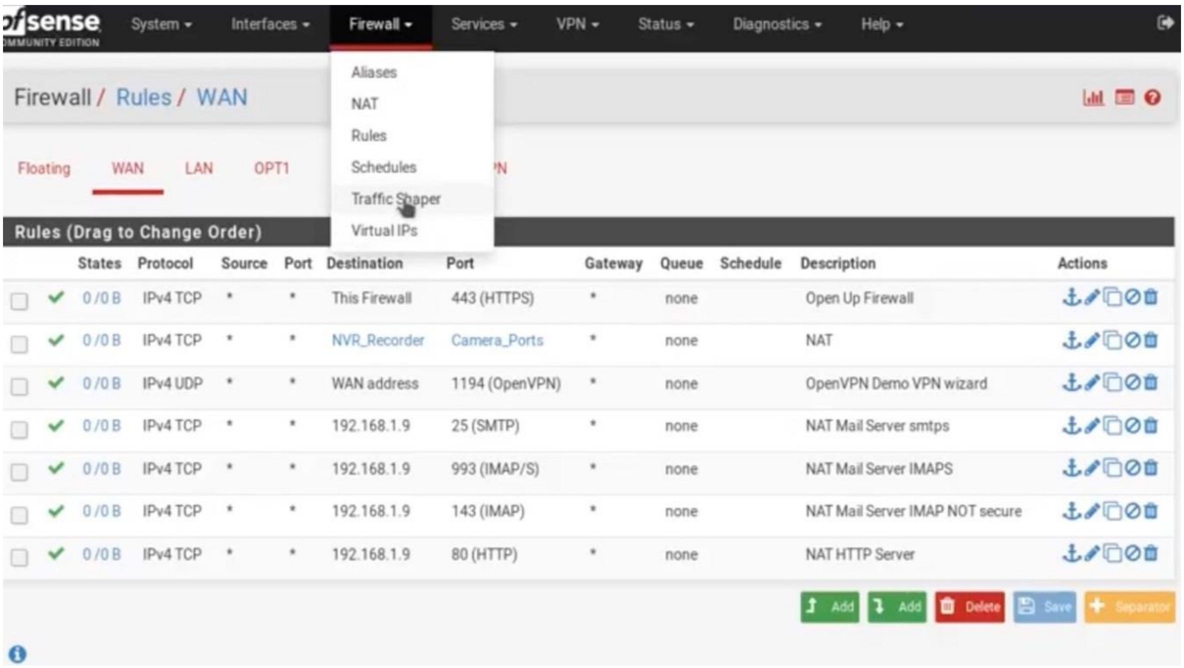

Fig 3.1 Traffic shaper

3.3 Traffic shaping wizard

Fig 3.2 shows that there are four ways of shaping the internet traffic that are:-

- Shaping by interface
- Shaping by Queues
- Shaping by limiters
- Shaping by wizards

Shaping by wizards is the option which was chosen because it is the all in one process for the first three. After so many trial and errors it was realized that shaping by wizards is less time consuming and less complicated as well as it combines it automatically generates the traffic queues, traffic limiters based on the configurations, options and rules which would have been selected and put in the wizard.

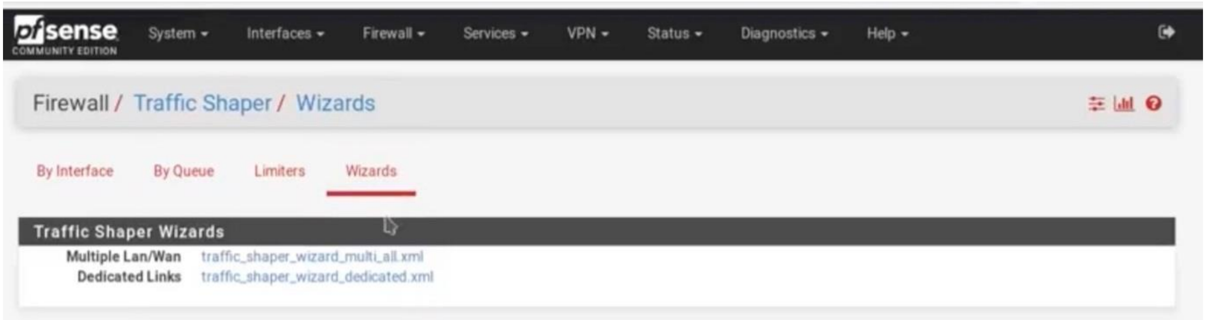

Fig 3.2 Pfsense traffic shaping wizard

3.4 Shaper configuration

Prior to starting traffic shaping, a speed test was done as shown in fig **4.1** and it was seen to be averaging at 50Mbps so the maximum bandwidth for upload and download were all given a maximum bandwidth of 50Mbps. The problem is not that the university has insufficient bandwidth but that the maximum bandwidth that can be attained at any given time must be managed utilized and optimized effectively, hence the need for traffic shaping for both incoming and outgoing traffic. Fig 3.3 shows the shaper configuration interface and the bandwidth allocated to both upload and download.

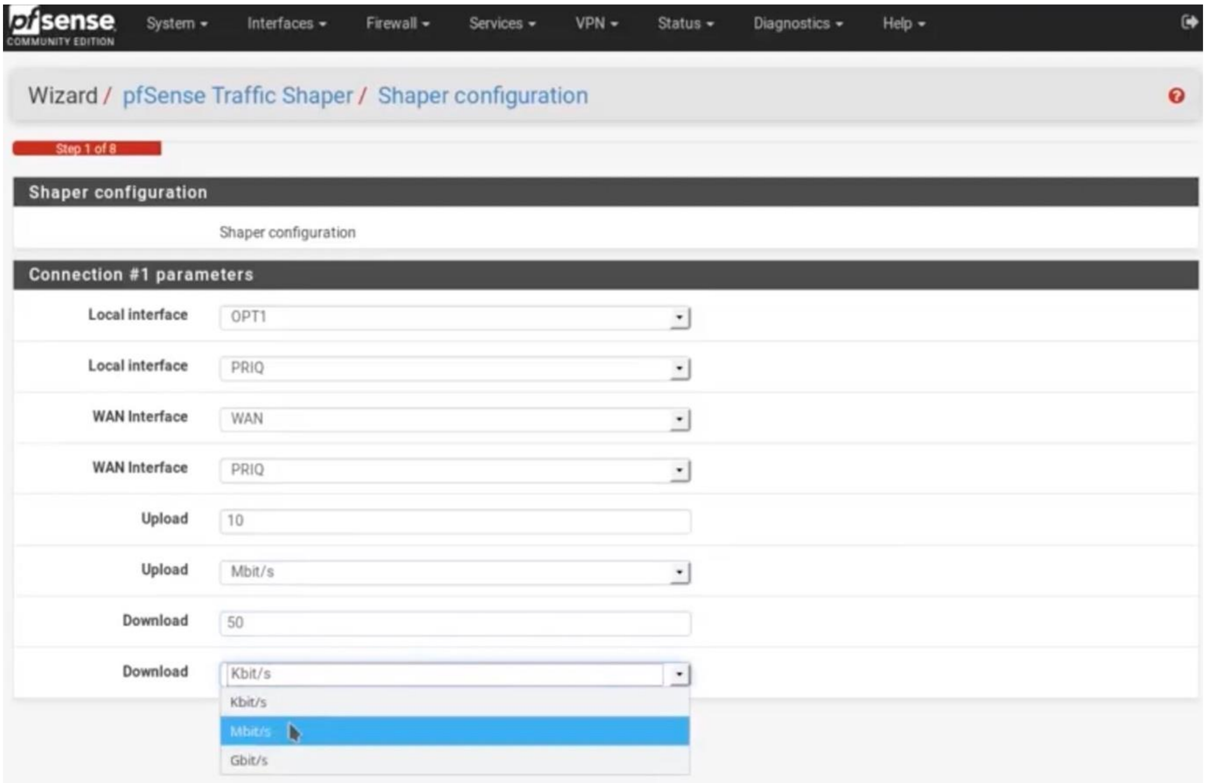

Fig 3.3 Firewall shaper configuration

3.5 VOIP prioritization

Fig 3.4 shows that VOIP traffic prioritization over the network was enabled. VOIP applications are been widely used in communication because of its convenience and low cost. VOIP traffic is is much sensitive to latency, packet loss and jitter than most applications. As mentioned in **2.4** it is important that university's network handles this relatively new demand by giving it high priority.

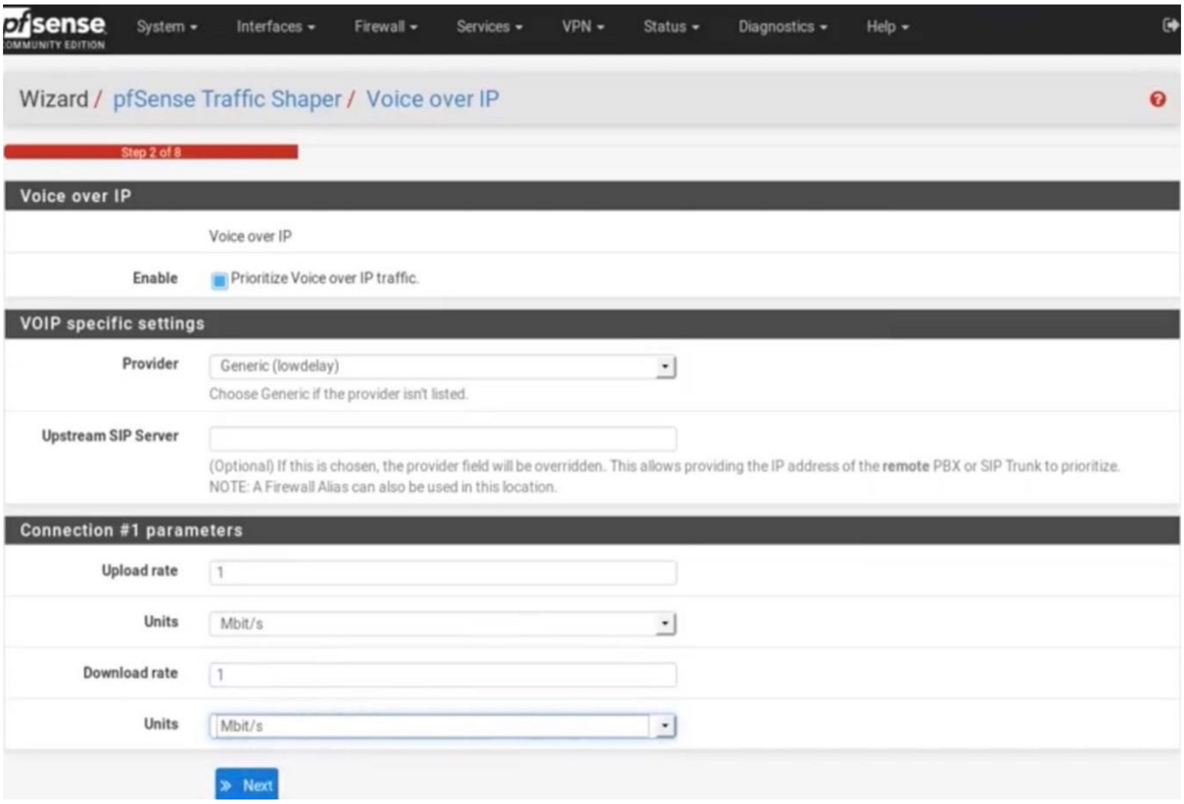

Fig 3.4 VOIP traffic prioritization.

3.6 Lower priority for peer to peer traffic

The traffic schedules and queues created won't work very well if peer to peer traffic priority is not lowered. Even if peak usage is assumed at certain times of the day, P2P applications, the computers are often left to transfer data throughout the day in an unattended fashion [3]. The process used to lower the P2P traffic is called aggregated rate limiting , all P2P traffic was limited to 15% of the available bandwidth at any given time, other than the averages of 60-70% it averages on the internet usage world generally around the globe. This however makes sure that casual users are not heavily affected. Besides using the firewall, this can be dealt with on the DNS by limiting traffic on expensive and congested links.

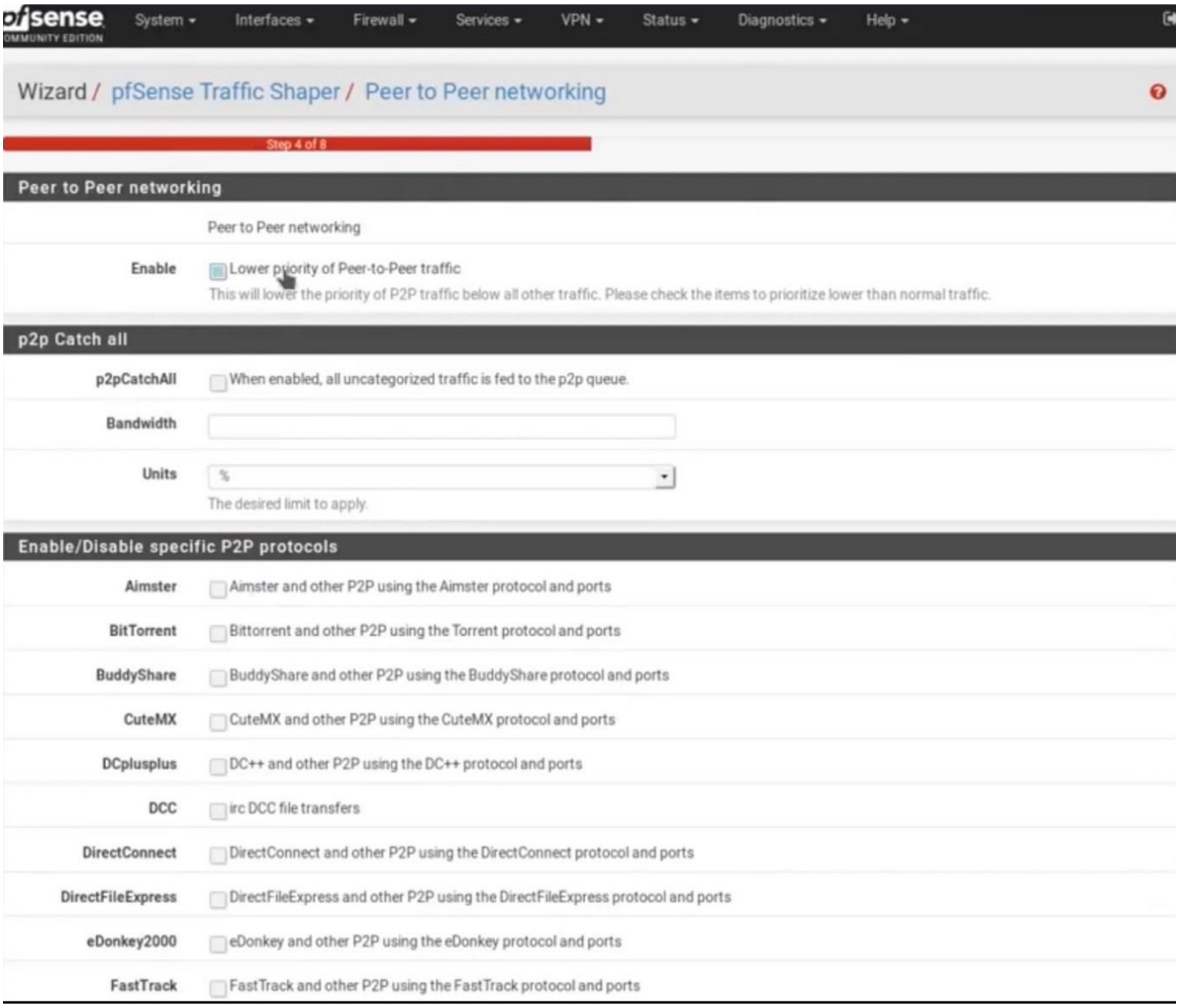

Fig 3.5 Lowering priority of peer to peer traffic.

3.7 IPV4 and IPV6 all enabled

For network performance, a test of the difference between IPV4 and IPV6 was done by trying to emulate what majority of people do, thus to search the web. Top sites that support both IPV4 and IPV6 were visited. The curl utility was implemented and then connect time and total time values for both IPV4 and IPV6 were compared. The following sites sites were compared

- google.com
- facebook.com
- youtube.com
- wikipedia.com

- Netflix.com

Results from this are shown in table 4.6

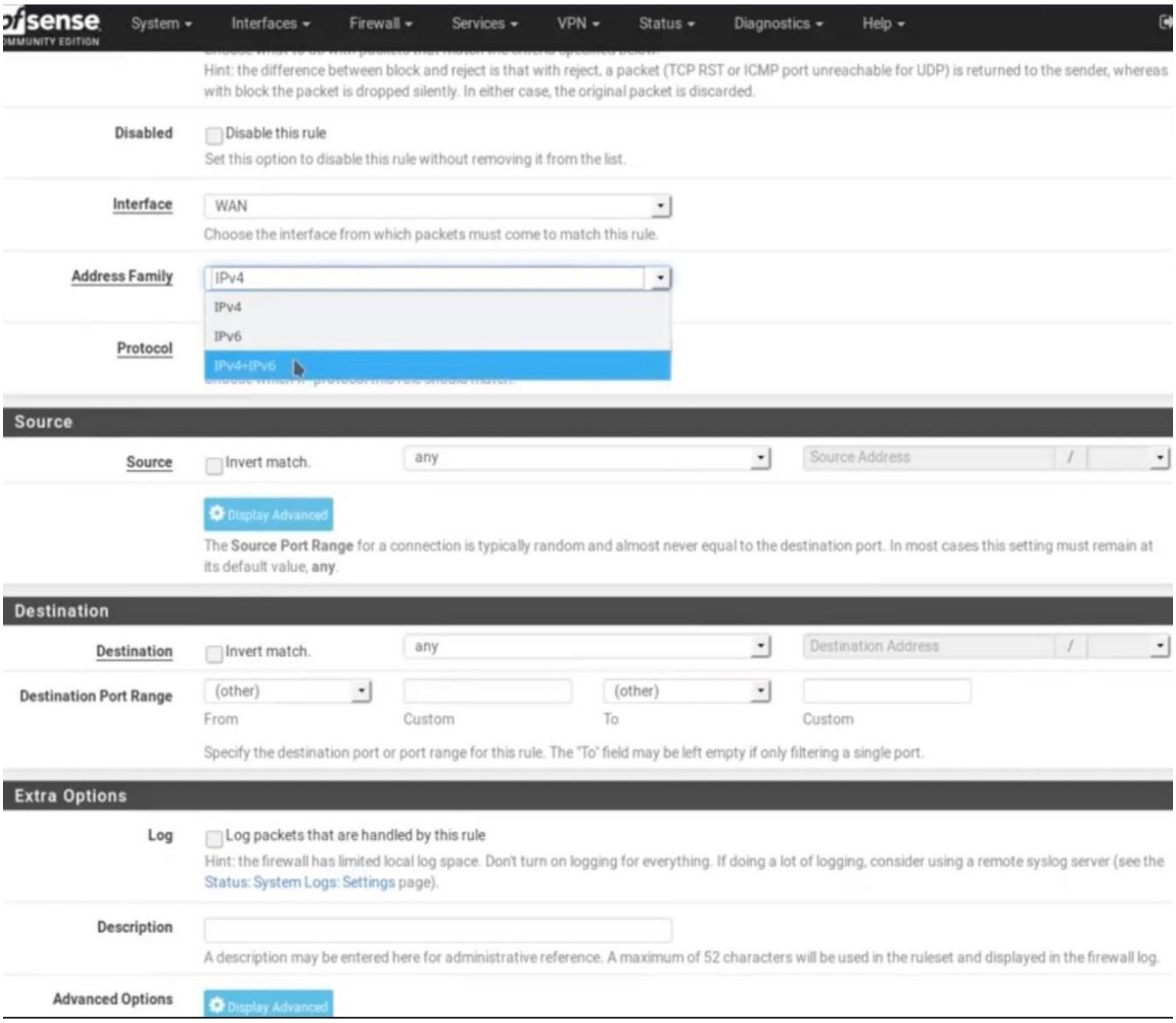

Fig 3.6 configuring IPV4 and IPV6 as the address families

3.8 Per user bandwidth restriction

Bandwidth was restricted per user in an effort to cap the network traffic indirectly. Before partaking this, a speed of the internet was run, and as shown in Fig 3.6 download speeds were found to be 1.63Mbps and upload speeds were 42.41Mbps. So because of such speeds, those whom have machines with high processing power like the HP Core i7 that which have network cards which supports such speeds will suffocate the bandwidth for those with machines or devices that do not support such speeds, so in a move to improve network performance and overall efficiency and also to avoid bandwidth wastage by people with such devices the traffic was capped at 0.90Mbps for upload and 0.60Mbps for uploads. A speed test was run again and the results were as shown in Fig 4.1

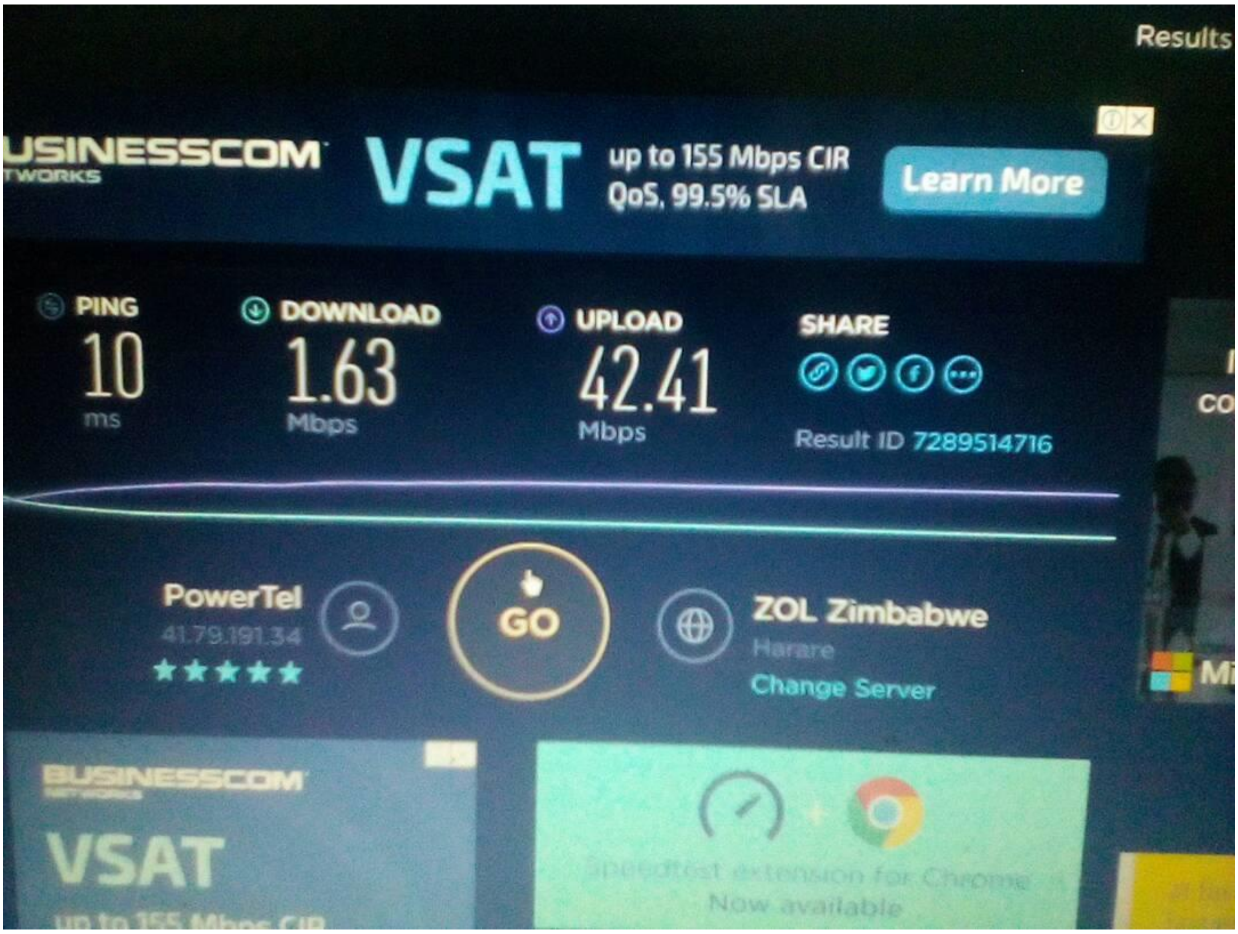

Fig 3.7 Internet speed before capping

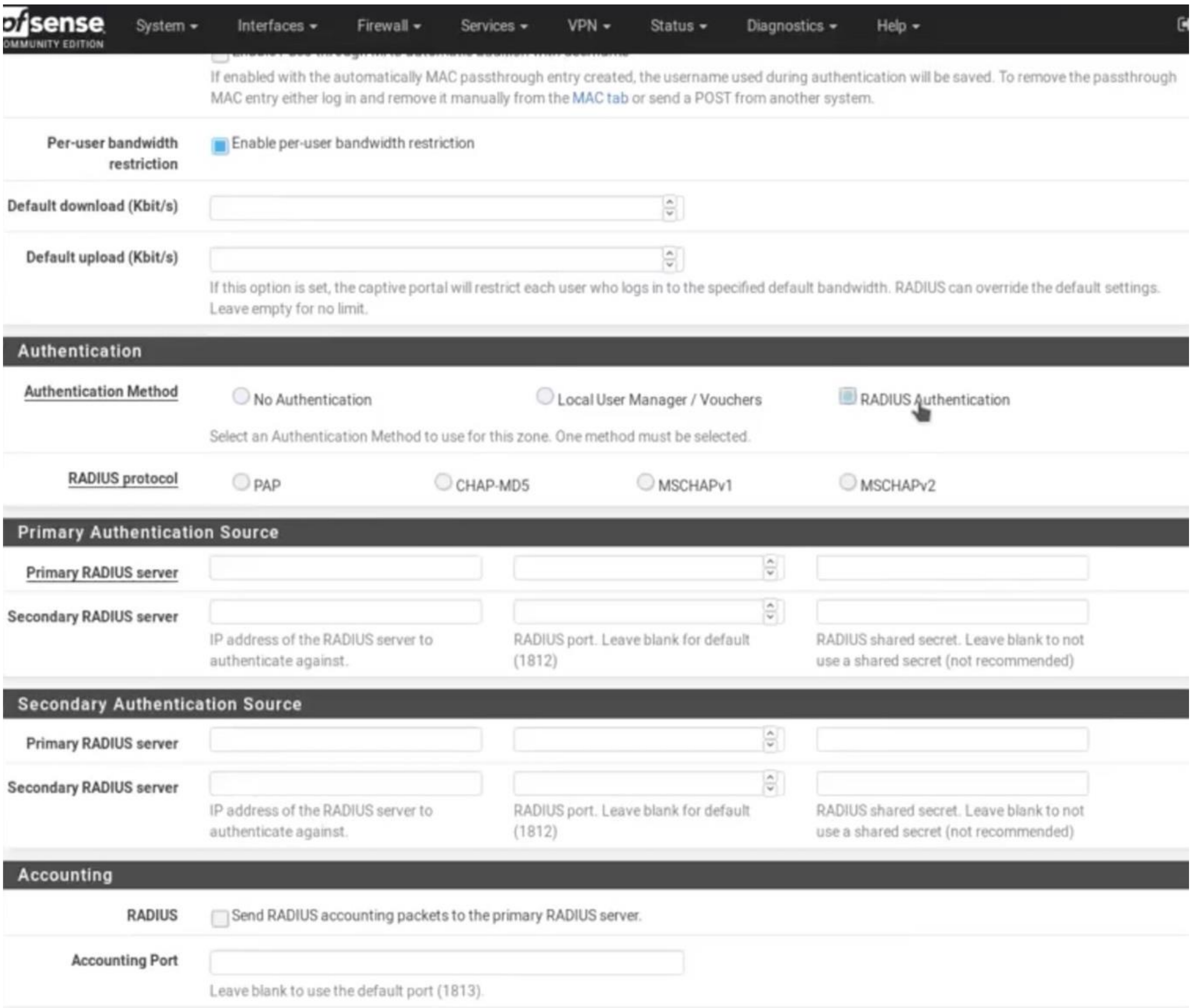

Fig 3.8 Bandwidth per user restriction on the firewall

3.9 Multi Router Traffic Grapher (MRTG)

MRTG is a tool or a software that is used to monitor traffic load on networks. In this documentation, the software was used to monitor and graph router statistics. The powertel router is the one which was of central focus. The University's IT team was initially monitoring the traffic using the software firewall called SonicWall, however SonicWall performs better as a firewall other than a traffic grapher so MRTG was used instead. MRTG provides a convenient way to gather statistics from routers via SNMP and the statistics are then presented in a graphical though a web server. Anther software called Netflow analyzer was used to for the same task for complementary purposes.

3.10 Conclusion

This chapter looked at the currently existing bandwidth management strategies at the Midlands State University. It has also evaluated the effectiveness of these methods in optimizing the internet bandwidth at the institution. In this chapter fluid and dynamic bandwidth management strategies are proposed. The strategies are to be implemented using evolutionary prototyping methodology on a live network at MSU. To get the requirements for the proposed system, a critical study of the Midlands State University was done. This chapter also looked at the tools that are to be used and how they will be implemented and tested.

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CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter discusses the results of bandwidth management strategies implementation at MSU.

4.2 Data Presentation and data analysis

Bandwidth was restricted per user in a way to cap traffic to utilize the bandwidth and and at the same time avid traffic congestion. Fig 3.7 show the maximum download and upload speeds before traffic capping as produced by the speedtest network tool. The maximum download speeds were 1.63 Mbps and upload seeds were going as high as 42.41 Mbps. This however had a negative impact on managing the bandwidth. Unrestricting the bandwidth the bandwidth per user was only beneficial to individuals with machines which have high processing power and which have bigger and faster network cards. These machines would access the internet at such speeds but in the process consuming a larger share of the bandwidth. The internet was capped at 0.6 Mbps for download and 1.0 Mbps for upload and results obtained using the speedtest network tool are shown in fig 4.1.

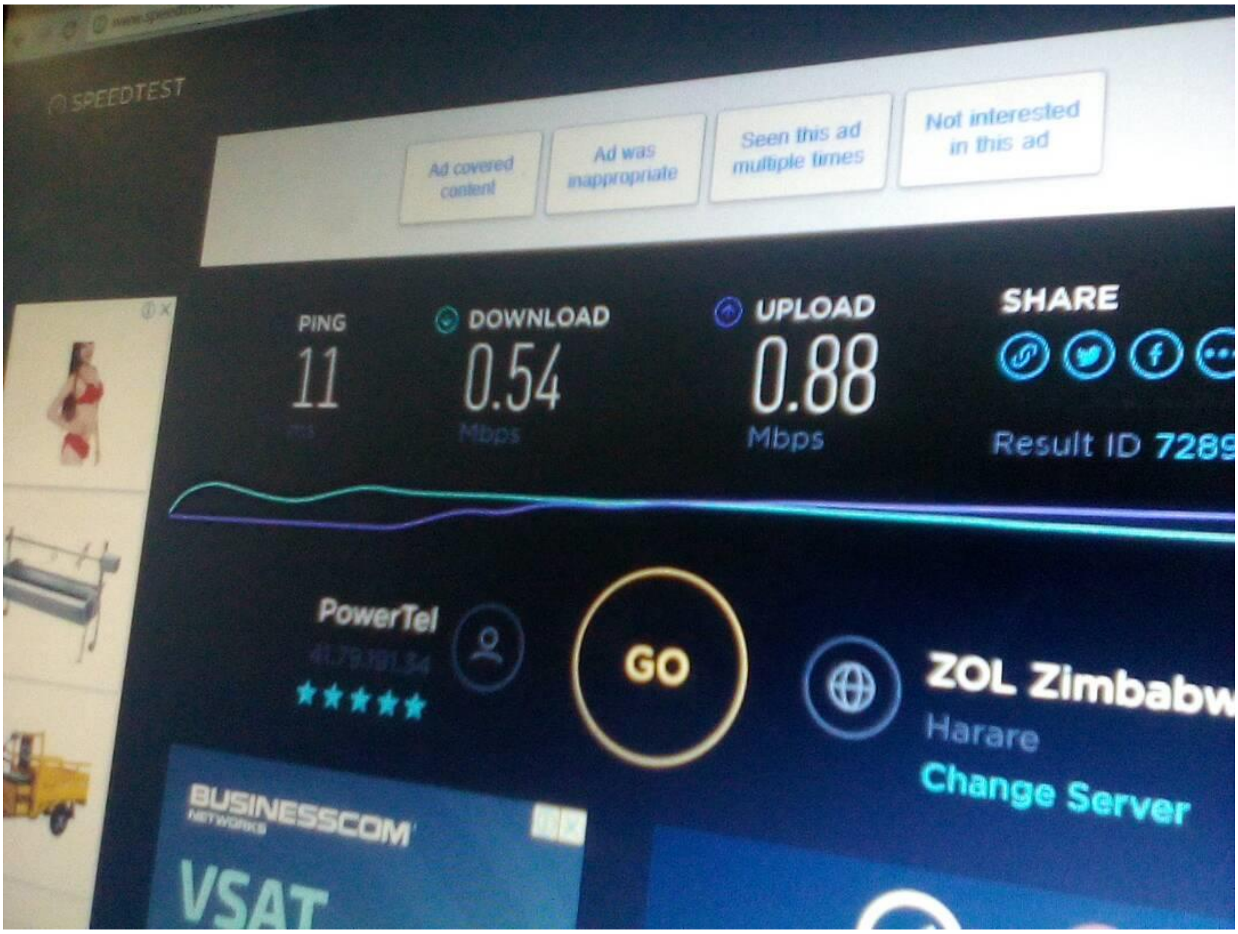

Fig 4.1 Traffic flow rate after capping

When more bandwidth is made available, all the network applications sharing that link will seek to consume it and keep the pipe full. In other words as soon as the bandwidth is increased it is consumed, and there is no guarantee that mission critical applications have received their share of the whole bandwidth. In short attempting to solve the shortages by merely buying more bandwidth without regulating regulating it is often a waste of money. Secondly banning particular internet connections like facebook, youtube and whatsapp may free up more bandwidth but will defeat the intent of internet as a global communication network.

Moreover computer users on a network that bans access to some applications of internet are likely to find ways to circumvent these bans. By contrast users on a capped network will be less inclined to bypass the system since their connections will still work. Bandwidth capping provides cost effective, guaranteed quality of service without shutting users off from parts of the global network.

While bandwidth capping provide a more effective solution than the alternatives, it too has limitations. The network can be hindered by more because bandwidth caps are only effective as the priority classifications made by the network administrator. However this limitation was solved by priority queuing as shown in chapter 3. However on the bandwidth management side even with bandwidth caps in place, other factors can contribute to poor network performance even though the bandwidth is managed properly.

Fig 4.2 shows the maximum inbound and outbound traffic traffic on MSU powertel main router after implementation of the bandwidth management strategies which include traffic management through traffic shaping and capping, traffic scheduling, priority queuing, lowering priority traffic for peer to peer trafficking. Fig 4.3 shows min/max/average bandwidth received from powetrel and Fig 4.4 shows bandwidth utilization of MSU internet as a percentage since Mid-April when implementation of the bandwidth management strategies started, hence since the Neflow analyzer software was obtained which explains why there are no values for March and the First half of April.

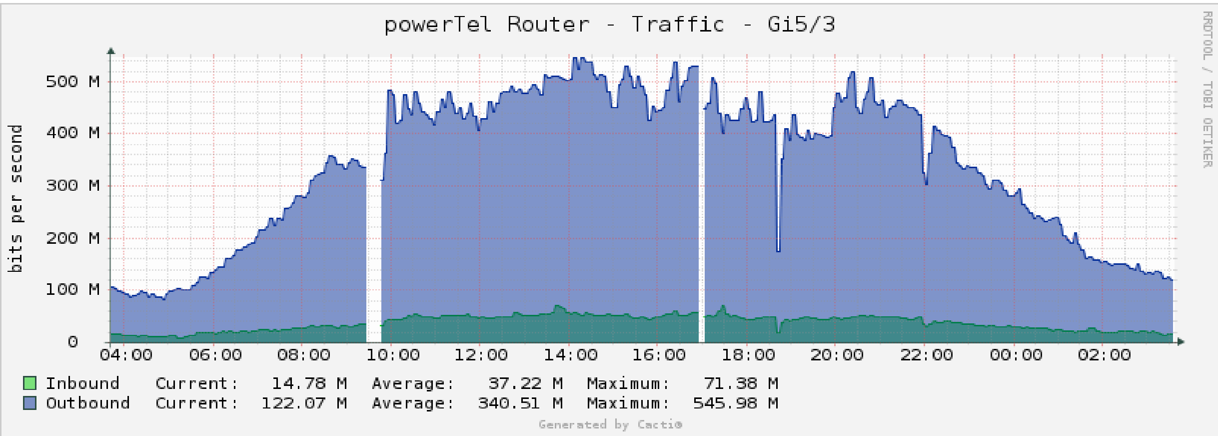

Fig 4.2 Max/Ave inbound and outbound traffic on MSU powertel main router

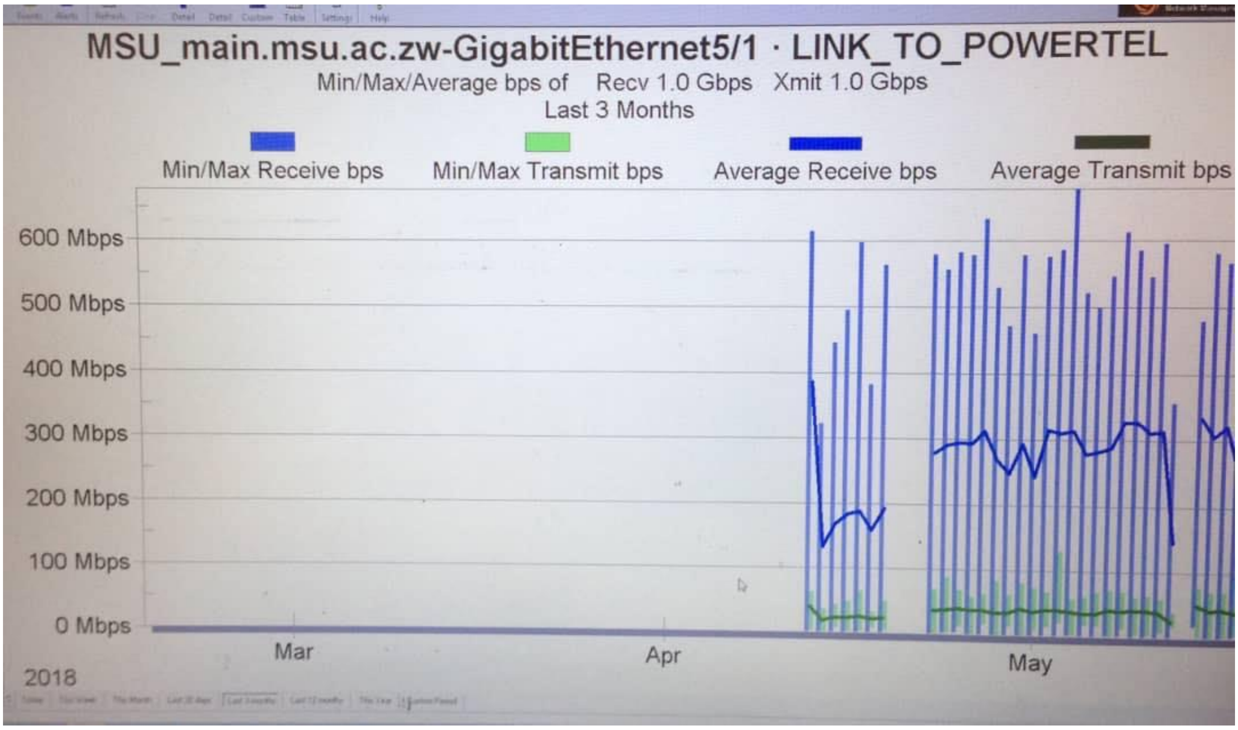

Fig 4.3 Min/Max/Average Mbps of Received Bandwidth from Powertel.

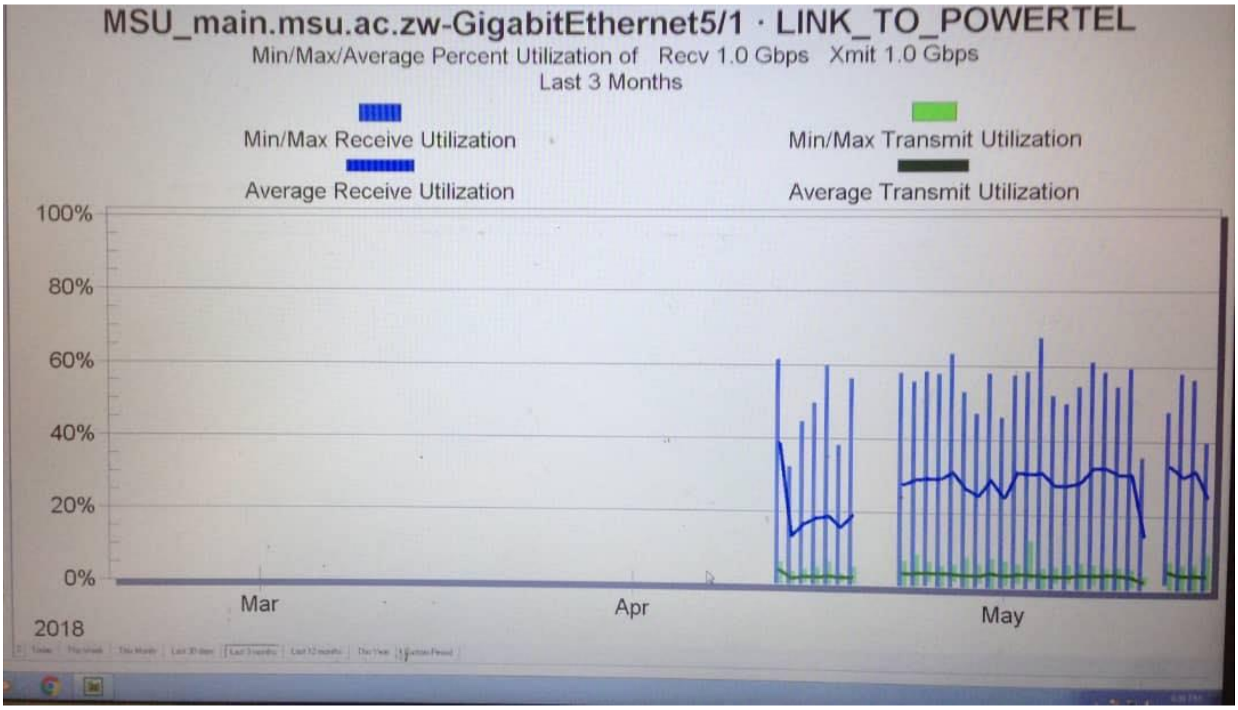

Fig 4.4 MSU main campus bandwidth utilization as a percentage

Before the start of this project there was no record of how much bandwidth is being utilized, how much is really required or what really is consuming much bandwidth. The information that was only available is how much is being bought from powertel and how much is given to the main campus by the ISP and how much is being given to Telone graduate school of commerce and law. There was no strategy at all for managing the bandwidth and there was more network congestion. Fig 4.2 shows the bandwidth utilization in the beginning phase of the implementation phase and averagely 10% bandwidth was being utilized. After implementation strategies as proposed in chapter 3, Fig 4.4 shows that the utilization percentage was on a rise, it rose to an average of 30%.

Alternatives to per user bandwidth restriction, priority queuing, lowering priority for peer to peer trafficking, traffic scheduling and traffic shaping are increasing the total amount of bandwidth and completely denying access to particular internet servers, but the bandwidth management strategies employed in this report are the cost effective of them all.

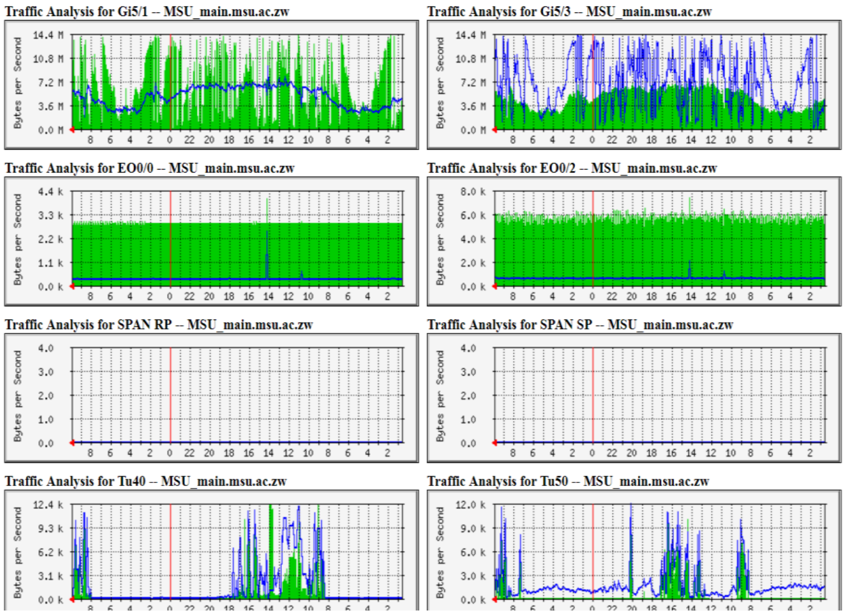

Fig 4.5 Traffic analysis graphs for MSU_main.msu.ac.zw

4.3 Conclusion

This chapter presented the results of bandwidth management strategies implemented at MSU. The evaluation experiments were carried out on MSU live network with the help of the university's chief IT technician Farai Mwabvu and under the guidance of MSU IT Director Mr Liberty Dandira. The results from the study established that the proposed bandwidth management strategies were able to manage the bandwidth through traffic management. The experiments also clearly showed that the strategies were capable of bandwidth optimization as will be discussed in chapter 5 under findings.

References

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CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter focuses on discussions on findings of the study of the Midlands State University's bandwidth management strategies. This chapter also presents critical review and recommendations for future work.

5.2 Findings

The data which was collected in due course of the project revealed that the Midlands State University institution was not keen on bandwidth management. The IT chief technician reported that the department does not have a plan for bandwidth management. This study however argues that that the best method to implement bandwidth management strategies is by managing the users behavior. This is in line with [1] affirms that in order to optimize bandwidth, traffic management is essential. Traffic management was implemented in various ways and in all the ways positive results were found. Traffic capping through per user bandwidth restriction had a much significant impact in optimizing the internet bandwidth by making sure that every connected to the internet gets a fair share of the internet and those with machines with bigger processors do not suffocate the scarce resource disadvantaging those with machines with small machines. Traffic capping also met the objective of improving the network performance since this effective bandwidth approach was successful in forestalling traffic congestion, but it was complemented in doing so by limiting the priority of peer to peer trafficking which greatly causes traffic congestion. Even if peak usage is assumed at certain times of the day, P2P applications, the computers are often left to transfer data usually throughout the night in an unattended fashion [2]. Aggregated rate limiting was found to be the best way to lower P2P traffic. Limiting priority for peer to peer trafficking mainly used for gaming and torrents made sure that casual internet users were not affected by peer to peer traffic and this however helped in meeting the objective of limiting non critical traffic in such a way that it does not affect critical traffic. Traffic management through traffic capping by per user bandwidth restriction, and aggregated rate limiting of peer to peer traffic are the major ways of limiting bandwidth usage at Midlands State University in a way to avoid bandwidth wastage but at the same time not compromising the overall network performance but rather improving the network performance as evident in the results and analysis of this report and also the current internet performance improvement at the institution. However even if the bandwidth is managed efficiently, network performance improvements also depends on some other factors notably the network architecture, interference avoidance techniques and the type of equipment used.

5.3 Limitations

As mentioned in chapter two, the three main techniques for bandwidth management are, traffic management, caching and compression. However due to financial constraints of the University, web caching was not able to be implemented since the university was not able to finance a web cache. The one that was once available malfunctioned long lack. The firewall that was used for traffic management is a software firewall, but however for better traffic management a hardware firewall and software should work hand in hand, but due to financial constraints the institutions IT department does not have a hardware firewall which is a major setback on the network architecture as it makes it dubious. The software packages used during the project were all trial versions, and they did not perform all the functions that were required for the project since some of the features are only available in premium packages, efforts to purchase the premium packages online were fruitless since all international l transfer of funds from banks that operate in Zimbabwe were forestalled due to economic reasons. However regardless of the fruitful efforts in bandwidth management which also helped in improving network performance, the network performance will be far much improved if the network equipment used supports the capacity required. The current access points that are being used at the university hostels are Aruba 4.2 which only gives internet access to only a maximum 30 connected users at any given time, the rest will be just connected but they will have no internet access. These access points are office access points, not enterprise edition and with students averaging 2 devices per individuals it means that in a whole hostel of 60 students, all will be connected to the wifi but only 15 students will be accessing the internet bandwidth hence only 15 students will be having internet access.

5.4 Recommendations

In the process of carrying out this study, several areas of further study have presented themselves. Due to financial reasons bandwidth management was only implemented through traffic management, so for anybody wishing to refine the project we recommend that caching and compression equipment be bought, thus a web cache and installation of a hardware firewall.. However the study also targeted at coming u up with affordable bandwidth management. The university should also use equipment that has the ability to support the network capacity, for instance the available aruba office access points which support a maximum of 30 devices per any given time should e replaced with enterprise access which support at least 150 devices per any given time. Purchasing enterprise access points would not only mean that a lot will be accessing the bandwidth, it would also mean there are less and spaced access points hence lower levels of interference between access points on their own hence better network performance at the same more optimization of the available bandwidth. For much effective bandwidth management, the university should purchase equipment that supports Deep Packet Inspection (DPI). The network technicians should not be only guys who studied information systems, they should start engaging telecommunications personal to help them manage the bandwidth and to also do a more detailed radio network planning for they have broader knowledge in those critical departments than the currently employed IT personnel. Users also need to be educated bandwidth and internet usage, and also policies should be set.

References

[1] R. Flickenger, ‘’How to accelerate your internet bandwidth’’, A practical guide to Bandwidth Management and Optimization using Open Source Software. INASP/ICTP, October 2016