NETWORK UTILIZATION AND PERFORMANCE AT KABARAK UNIVERSITY, KENYA

BY

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DECLARATION

DECLARATION BY THE CANDIDATE:

This is my original work and has not been presented for a degree in any other university.

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DEDICATION

I dedicate this work to my wife, Irene and my daughters Faith, Lynne and Melannie who have been my source of inspiration, support and constant encouragement. I dedicate this work also to my beloved parents who have always taught me to work hard for the things I aspire to achieve.

ABSTRACT

Scalable campus-wide network with high speed connectivity is a basic necessity for institutions of higher learning. However, without good network management policies and optimization techniques, network scalability becomes a difficult undertaking. This study critically examines the current state of bandwidth usage and network utilization at Kabarak University. The study sought to establish holistic approach in addressing bandwidth inadequacies that arises from query optimizations; to identify best practices for efficient network utilization; to quantify quality of service metric and acceptable level of user satisfaction; to determine effectiveness of proxy server load balancing in reducing network latencies; to establish users perceptions and opinions about the current bandwidth optimization policies and finally to implement effective network utilization techniques. From the literature, conceptual framework was developed based on Heron-Middleware theoretical framework architecture review. Questionnaires, interviews and observation were primarily used as research instruments to collect data. The study adopted quantitative research methodology. Stratified random sampling method was used to draw samples of 20% from 886 students and 75 staff respectively. To empirically examine this, a survey was conducted on 192 full-time staff and students focusing on the following variables: perceived quality of service, latency management, bandwidth optimization, Query optimization, proxy load balancing, end-to-end network visibility, content filtering and ICT policy. The survey was conducted in Kabarak University. The data collected were analyzed empirically using Statistical Package for Social Scientist. Inferential statistical analysis was done and the results show that various network utilization strategies were implemented in Kabarak University network and comparison is made on the network performance before and after the implementation. From the findings there is clear indication that good end-to-end visibility mitigates network risks proactively therefore, deliver real value of optimized quality of service and acceptable level of user satisfaction hence cost saved. The research findings further shows that latency management mediates the effect network performance by keeping network latencies in check. In addition, ICT policies have serious influence on the network performance. Policies enhance user awareness on the importance of bandwidth utilization among all stakeholders on appropriate use of network resources. Finally, the research finding shows that adherence to recommended bandwidth capacity ratios leverages network utilization and available bandwidth thus, rationalizes IT costs. The study recommends that network and system administrators should focus baselining and trending of network resources to enhance reusable bandwidth; University management must invest on the right tools for enforcing policies to improve network utilization; create user awareness among all stakeholders on appropriate use of network resources by ICT support staff; ICT staff and university management should work in-hand to re-evaluate of the current ICT policy and network infrastructure redesign in mitigating challenges of suboptimal network performance.

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ACRONYMS

HTTP	-	Hypertext Transfer Protocol
ICT	-	Information Communication Technology
IT	-	Information Technology
ISP	-	Internet Service Provider
IIS	-	Internet Information Server
LAN	-	Local Area Network
SPSS	-	Statistical Package for the Social Sciences
WI-FI	-	Least-Frequently-Used
SQL	-	Structured Query Language
MYSQL	-	My -Structured Query Language
NSRC	-	Network Startup Resource Center
RRDtool	-	Round-Robin Database Tool
ICMP	-	Internet Control Message Protocol
GPL	-	General Public License
QOS	-	Quality of Service
CAT5	-	Category 5
CAT6	-	Category 6
TCP	-	Transfer Control Protocol
URL	-	Uniform Resource Locator
UTP	-	Unshielded Twisted Pair

DEFINITIONS OF KEY TERMS

Bandwidth: This is amount of data that can be carried from one point to another in bits per second (bps)

Browser: Software used for retrieving and viewing various kinds of information on the World Wide Web

Caching: Process of avoiding a roundtrip to the origin web server each time a resource is requested and instead retrieves the file from a local computer's browser cache closer to the user.

Client's browser caching: In Client's browser caching, web objects are cached in local disk drive

Client-side proxy caching: Web objects are cached inside a proxy server in which clients bypass through when browsing reduces round-trip delays between client and the origin web servers.

Latency: Any delay typically incurred in processing of network data.

Server-side proxy caching: Distributes or re-routes clients requests to the proper server-side proxies and this enables the web server to release traffic load hence reduced user perceived response time.

Transparent proxy: Transport proxy intercepts normal communication without requiring any special client configuration

Prefetching: It is a process of bringing back more than one type of objects in a single query.

Proxy server: Computer system that acts as an intermediary for http requests from clients seeking resources from other servers.

World Wide Web: This a hypertext-based, platform-independent means of displaying text, graphic, audio, and video information over the Internet (Labrecque, 2013).

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Today's institutional networks are under unprecedented pressure to deliver quality and optimized network services to end-users. The demand for network resources within institutions of higher learning is continuously increasing therefore, calls for optimization of network resources. Scalable campus-wide network connectivity with high speed plays critical role in delivering institutional sole mandate of academic, research, training and content to end-users. This demonstrates that network connectivity in institutions of higher learning is a prerequisite. According (Sharma, 2011, pp. 173-178); it is not practical for any institution of higher learning to function without connectivity to the wider academic community. With the global quest for knowledge, it is imperative that institutions of higher learning manage their networks to ensure efficient access and availability of institutional resources globally (Kashorda, 2014). Through optimization of network resources, institutions of higher learning reduce network loads and network bottlenecks that impede on network performance acceleration. Furthermore, it leverages network performance by reshaping and grooming of network traffic therefore, reduce recurrent costs on network maintenance and bandwidth upgrades.

Policy implementation plays a significance role in optimizing network utilization and performance. Policies provide the necessary controls needed by network administrators in managing available resources in accordance to standards governing network access and usage policy. Enforced network access and usage policies ensures adherence to best practices by end-users. Without enforced network access and usage policies, the amount

of available bandwidth shrinks drastically resulting in unrestricted end-user environment, where only few users consume the majority bandwidth causing degraded bandwidth capacity (Sharma, 2011, pp. 173-178). In this kind of end-user environment where only few users consume larger percentages of the available bandwidth at detriment of other end-users, user awareness is the only key solution. According to (Chitanana, 2012, pp. 66-76), user awareness is the most beneficial approach than technical solutions. Conversely, institutions of higher learning which have successfully implemented techniques for optimizing network utilization and performance have registered tremendous success in managing their network resources effectively.

1.2 Background Information

The concept of network utilization and performance is nothing new within institutions of higher learning. Network utilization and performance has been extensively researched in different dimensions from policy-based bandwidth optimization, query optimization, latency management among other strategies but little has been accomplished towards attaining bandwidth sufficiency despite large investment on bandwidth upgrades by institutions of higher learning. Currently, institutions of higher learning are formulating measures for managing network and bandwidth; however, these measures have fallen short.

Though there have been extensive research studies on network utilization and performance, this research study focuses on implementing effective approaches in optimizing network utilization and performance at Kabarak University. This research study is essential because World Wide Web has become the most commonly suitable

media for institutions disseminate information and transact business worldwide through web-based applications. *"With the increased popularity and activity in World Wide Web, most institutions of higher learning are pushing to have more content and web presence"* (Lynn et al., 2002, pp. 35-49). This is well demonstrated by webometric ranking of institutions of higher learning (Cybermetrics, 2014). This demand for web presence and provision of reliable network resources has outpaced the capacity of the network infrastructure increasing network traffic loads that cause congestion issues and high latencies that result into slow information retrieval and browsing ensuing to *"World Wide Wait"* (Datta et al., 2003, pp. 1425-1444).

The exponential growth of networks without scalable solutions has ultimately resulted into unreasonable loads, latencies and unacceptable levels of quality of service leading to unnecessary network bottlenecks (Obraczka, 2000, pp. 1-10). With the ever increasing demand for bandwidth capacity coupled by subsequent growth of institutional networks, have necessitated the need for optimizing network utilization and performance therefore, it is more tenable to optimize the existing bandwidth rather than going for higher bandwidth since bandwidth utilization is directly proportional to network efficiency (Smith, 2012). It is of primary importance to note that bandwidth is a valuable resource that cannot be ignored by any institution or organization since can easily turn into a liability cost if proactive measures in optimization are not taken care of. Moreover, most institutions are currently in a dilemma on how to optimize and manage the existing bandwidth capacity in respect to satisfying end-users needs and meeting institutional expectations without investing on additional bandwidth.

A background research conducted was by the researcher in Kenyan Universities, points out clearly that network utilization and performance techniques have been deployed towards optimization of network resources. Egerton University, for instance, distributes their traffic loads via different proxy servers. This allows users to connect to a proxy server with less traffic loads hence reduce congestion. Moreover, Egerton University uses virtualization to optimize available resources to reduce devices attached to the network therefore, ensure effective network utilization and improved network performance. Virtualization helps in scaling the network and ensures no downtime is experienced by end-users. Egerton University utilizes Virtual Local Area Network segments to manage and enhance network performance.

However, techniques deployed by institutions of higher learning in Kenya only meet partially end-users needs thus limit quality of service. This research study, in turn, attempts to resolve this inherent network problem holistically by implementing effective techniques for optimizing network utilization and performance in order to meet end-user needs and institutional expectations.

1.3 Problem Statement

Given the evolving nature of networks and the unprecedented pressure on bandwidth demands, a scalable campus-wide network with high speed connectivity has been a problematic issue in institutions of higher learning towards executing their mandatory role of academic, research and training. This problem has been compounded by high network latencies occasioned by unnecessary network traffic bottlenecks that cause traffic buffer overflows and packet losses resulting to inherent *http* connection delays.

Due to this, *http* requests are retransmitted, generating immense network traffic that cause proliferation of network broadcast storms within the network leading to lower throughput and congestion. Despite of significant investments on bandwidth upgrades, many institutions are still finding difficulties in attaining bandwidth sufficiency that completely satisfies end-users needs and meeting institutional expectations. The unrelenting network traffic growth rates and bandwidth demands which are not tailing off, poses a great challenge to institutions of higher learning towards providing reliable network connectivity and timely delivery of network resources. With a resource valuable like bandwidth, guaranteeing service availability poses monumental challenge because of bandwidth intensive applications and constant network threats like denial of service attacks, SYN flood requests which results to service downtime and suboptimal network performance. These evolutionary trends and challenges that we experience in today's institutional networks necessitated further research into the techniques for optimizing network utilization and performance at Kabarak University in order to come up with a viable solution to mitigate these inherent network traffic problems.

1.4 Aim of the Study

To critically examine the current state of bandwidth usage and network utilization at Kabarak University in order to implement effective strategies for optimizing network utilization and performance.

1.5 Specific Objectives of the Study

The specific objectives of the study were;

(i) To identify best practices for efficient network utilization.

(ii) To assess Internet Quality of Service and acceptable level of user satisfaction.

(iii) To assess effectiveness of proxy server load balancing in reducing network latencies.

(iv) To ascertain the current status of network utilization and performance.

(v) To establish a holistic approach for query optimization in addressing bandwidth inadequacies.

(vi) To implement effective network utilization techniques.

1.6 Research Questions

The research problem stated above led to the following research questions:

(i) What are the critical challenges in bandwidth management and query optimization for expanding networks?

(ii) What are the best practices for efficient network utilization?

(iii) What is the current state of Internet Quality of Service?

(iv) What are the best practices in attaining proxy server load balancing without impeding on bandwidth optimality?

(v) What are the challenges facing bandwidth and network utilization policies?

(vi) What are the challenges in implementing network utilization strategies?

1.7 Assumptions

The research study assumed that effective strategies and policies are in place to facilitate effective utilization of networks. The research study assumed that there is no service downtime experienced during the research study period.

1.8 Significance of the Study

Studying the benefits for optimizing network utilization and network performance is

paramount for numerous reasons. The results of this research study provided valuable information on efficient strategies utilized to deliver quality of service that meets end-users needs and institutional expectations. Secondly, the research study is resourceful in management and optimization of the available bandwidth more effectively therefore, reduce the unprecedented pressure on bandwidth needs and expending costs on bandwidth upgrades incurred in Kenyan universities. The results of this research study further, provides insights to university management authorities' to make informed decision on the right amount and cost of bandwidth required over a specified period of time. The results of this research benefits institutions of higher learning in developing progressive bandwidth management policies that correspond to the institutional needs and user expectations. The results of the research finding assist network administrators in coming up with complete organizational end-to-end network visibility therefore, reducing estimated time of return period. The results of this research study further provide the necessary insights required by institutions of higher learning on efficient strategies for optimizing network utilization and performance. Finally, this study contributes to techniques for optimizing network utilization and performance literature.

1.9 Scope and Limitation of the Study

This research study focuses on techniques for optimizing network utilization and performance at Kabarak University. The main limitations of this research study are inadequate resources, access and time frame. Low hardware and software specifications for server's constrained on tangible research findings of this research study. The available bandwidth throughput restricts on the research study owed to limited bandwidth available and frequent network service downtimes.

1.10 Summary

This chapter began with an explanation of the background and rationale to the current research study, followed by closer look at the problem statement, research questions and key research objectives. This chapter further outlines the structure of the thesis and summarize with a discussion of the significance, scope of the study with associated limitations of the current research. Chapter two of this research study presents a literature review in regards to the research subject.

CHAPTER TWO

LITERATURE REVIEW

This chapter discusses the concepts and strategies associated to effects of bandwidth management and network utilization on organizational or institutional performance. Consequently, the strategies focus on the ways of providing Quality of Service and effective ways of network utilization and performance at Kabarak University. The technological advances and increased use of the networked devices have led to mapping out of several strategies in search for solutions of improving network utilization and performance without impeding on quality of service.

2.1 Bandwidth Management and Optimization

"Bandwidth is defined as the amount of data that can be transmitted in a fixed amount of time and expressed in terms of bits per second (bps)" (I.N.N., 2013). It is important to note that bandwidth is an exceptionally valuable and scarce resource that is shared among many existing networks. "Bandwidth Management is described as a general term that depicts various techniques, tools and policies deployed by institutions or organizations to enable efficient use of its bandwidth resources" (Chitanana, 2012, pp. 66-76). Bandwidth management involves bandwidth allocation to critical applications and resources within the network. Without appropriate mechanism in bandwidth management and optimization, most applications and users will definitely take control of all available

bandwidth causing denial-of-service to various critical network resources and applications (Kassim et al., 2012, pp. 1-8). There are several techniques used in bandwidth management and optimization for instance; Caching which stores frequently used *http* requests in cache disk to avoid retransmission of user request multiple times. Data Compression strategy involves reduction in size of data to be transmitted. Bandwidth prioritization allows allocation of bandwidth based on the importance of the application. Moreover, distributed content allows content to be distributed from single location to multiple locations closer to the client. Finally, user awareness is the ultimate preferred choice in bandwidth utilization because it educates the users about the importance of saving bandwidth (Deneen, 2002, pp. 1-4). Bandwidth optimization aspires to reduce unnecessary network traffic hence improves internet speeds and connectivity. According to (Chitanana, 2012, pp. 66-76), *"the primary objective of bandwidth optimization is to have the right amount of bandwidth in the right place at the right time for the right set of users and applications"*. Therefore, it is prudent and productive to use bandwidth management tools to allocate bandwidth to critical applications and users during peak times to avoid traffic congestion on a network (Kassim et al., 2012, pp. 1-8). With effective techniques for bandwidth management and optimization in place, network performance will improve significantly within any organization or institution.

2.1.1 Significance of Bandwidth Management and Optimization

Bandwidth management and optimization is a necessity for any institutional network infrastructure (Gakio, 2006). With the increased internet activity, the demand for bandwidth has overstretched its capacity therefore there is need to optimize the available bandwidth within institutions of higher learning. To achieve fully optimized bandwidth it

requires concerted effort both from the network administrators and interested institutions to invest on the right tools for bandwidth management. Bandwidth management tools ensure the existing available bandwidth is utilized well therefore unlocking more benefits to the institution i.e saving running costs spent on bandwidth upgrades. It ensures that any further investments on bandwidth is guaranteed and worth the investment (Gakio, 2006). It is important to note that good bandwidth management practices and policies reduces strain on institutional budgets therefore, enhances prudent utilization of resources and ensures returns on investment is totally attained. Therefore, it is important for network administrators to remain proactive in bandwidth management and optimization in order to achieve effective network performance. Moreover, institutional stakeholders must invest on bandwidth management tools before acquiring additional bandwidth (Gwynn, 2006, pp. 30-31). This ensures that the bandwidth usage for institutions cannot be monopolized by malicious network traffic (INASP, 2003, pp. 1-5). Finally, bandwidth management and optimization boosts significantly network performance by providing efficient utilization of bandwidth by reducing the amount of redundant data on Wide Area Network and increases network fault tolerance.

2.2 World Wide Web

The World Wide Web is defined as a hypertext-based, platform-independent means of displaying text, graphic, audio, and video information over the Internet (Labrecque, 2013, pp. 25-29). "*The World-Wide Web allows access to online information sharing within internationally dispersed group of users through browsers in which they run without regard to where information is, how it is stored, or what system is used to manage it"* (Berners-Lee et al, 1992). With the advent of emerging network technologies, such as

Wireless Local Area Networks, Local Area Networks, Gigabit Ethernet, Mobile network connections and Voice over Internet Protocol , the amount of network traffic generated over the internet has experienced tremendous growth in the most recent years, largely due to high demand and wide adoption of the Worldwide Web technologies (CAK, 2014). Therefore, the embracement of web technologies has set up an upward trend for web-based content development and dissemination (Zen, 2004). With this exponential growth of web, searching through web pages and retrieving relevant content has become a thorny issue to many World Wide Web users. This inference can be depicted by many queries supplied by users to search content from web pages is not sufficient enough to describe user's intentions as they contain short phrases and sometimes ambiguous (Yoon, 2009, pp. 145-158). Using query intents by analyzing query logs in web based applications increases hit ratio hence enhancing user satisfaction. According to research conducted by (Wu et al., 2011, pp. 414-421) shows that World Wide Web is congested with large amount of network traffic. The researcher figured out efficient method of filtering and summarization of web pages to satisfy users need. In this research, it focused on development the Personalized News Filtering and Summarization system which recommends personalized news to users in accordance to their preferences. Personalized News Filtering and Summarization system contains two research components: a filter that analyzes the news and summarization component that summarizes web news in web pages. The immense popularity of World Wide Web has made the Internet a paramount application platform for disseminating, retrieving and searching information. This raises concern on how users retrieve information efficiently from the web. Research done by web community emerged with efficient web data structure to model web documents in

which web objects have logical structures enabling reorganizing web objects to support information retrieval (Xu, 2008, pp. 20-31). This research combined latent semantic analysis and web clustering to identify user session aggregations in web access patterns. This enhances user's flexibility and effective way of information retrieval in web-based data management (Xu, 2008, pp. 20-31). *"With the advent of real time data and services such as Google apps, twitter, facebook, Whatsapp, blogs and others, has made it exceptionally easy develop and create web pages content around the world"* (Das, 2012, pp. 1-28). This has been occasioned by the tremendous growth of World Wide Web that can be accredited to the transference of web content.

2.3 Caching Technique

"Caching is a process of avoiding a roundtrip to the origin web server each time a resource is requested and instead retrieves the file from a local computer's browser cache or a proxy cache closer to the user" (Yang, 2007, pp. 535-538). Web servers or Proxy servers with a lot of internet traffic tend to be overloaded hence becomes the sources of the prolonged response time. Caching plays a central role in reducing the response time as perceived by World Wide Web users (Shim, 1999, pp. 549-560). Caching has been proved to reduce drastically bandwidth usage and internet traffic thus resulting to reduced proxy server loads. This has enhanced accessibility of internet in a more efficient way hence better utilization of bandwidth. Caching has been adopted as way of optimizing bandwidth and also has become a significant part of the World Wide Web infrastructure (Davison, 2001). Caching technique has been proposed in different dimensions by different researchers as a new approach to bandwidth optimization. Most companies that provide Internet backbone and Internet service providers have

implemented web caching as part of their network infrastructure to enhance transparency to end users and service subscribers for their services they offer (Zen, 2004). Institutions of higher learning, colleges and small medium enterprises that receive internet services from internet service providers have employed caching strategy as one way of utilizing bandwidth. These institutions and small enterprise companies are using a variety of sourced vendor caching products and services as a way of network utilization to increase performance and reduce networking connection costs and over reliance on bandwidth upgrades which is expensive to sustain in future. Some of the commonly used caching schemes are proxy caching scheme, web caching scheme, cache replacement policy, Hierarchical caching Scheme and Cache Configuration Management.

2.3.1 Proxy Caching Schemes

Proxy caching mechanism capture http requests from users and performs lookup for requested object in its cache then returns the object to the user. If the web object is unavailable, the cache goes to the web object's originating server and gets the object. The web object is then stored in cache and finally returned to the user (Obraczka, 2000, pp. 1-10). Proxy caches are set up at wide area network. The functional benefit of using proxy caching schemes in wide-area network is to save bandwidth, reduce latencies and improve response time in retrieving web objects. Initial research done by (Zen, 2004) on efficient web content delivery using proxy caching techniques explains only the technical aspects of caching and recent developments in proxy caching ; caching the "uncacheable" , multimedia streaming objects, various adaptive and integrated caching approaches. This research further focused on proxy caching that does not require any major changes in the networked environment therefore, accomplishing the economies of scale since multiple

clients are served. This proxy caching scheme does not rely so much on any changes with respect to protocols to original web servers and also require minimal end-user configuration efforts (Zen, 2004). This necessitated the development of algorithms for caching such as Popularity-Aware Greedy Dual-Size Web Proxy Caching Algorithms. In this approach the researcher developed on-line algorithm that effectively captures and maintains an accurate popularity and also proposed a novel cache replacement policy that uses such information to generalize the well-known Greedy Dual-Size profile of web objects requested through a caching proxy. Some of the key contributions from Popularity-Aware Greedy Dual-Size Web Proxy Caching Algorithm include an effective method for cache utilization; popularity information is rarely maintained and utilized directly in the design of cache replacement algorithms. Rather than other properties of the requests which are easier to capture in an on-line algorithm are used to indirectly infer popularity information, and hence drive cache replacement policies (Bestavros, 2000, pp. 254-264). Other policies that have been in used to optimize bandwidth like Least-Recently-Used which leverages temporal locality of web objects or documents that recently accessed are likely to be accessed again.

On the same note Least-Frequently-Used leverages the skewed popularity of web objects frequently accessed in the past are likely to be accessed again in the future. Finally, Largest-File-First policy which leverages small web objects have a higher probability of being referenced again in the future (Bestavros, 2000, pp. 254-264). In this Popularity-Aware Greedy Dual-Size Web Proxy Caching Algorithm approach, it is noticeable that it only deals on how to optimize bandwidth using web caching technique leaving out prefetching technique in which if they are combined together it would have assisted the

client or user to reap maximum benefits of internet delivery and efficient network utilization. Proxy caches are widely deployed mainly to accelerate user http requests hence enhancing content delivery over internet. Due to the large size of web object, most proxy caching algorithms prefer to cache partial content data rather than the entire object. These http proxies act as intermediaries between a client and server during http data exchange. Therefore user http requests are tunneled through http Proxies which primarily serve as content caches in enforcing content policing and user monitoring policies. (Telekom, 2011, pp. 797-802).

2.3.2 Reverse Proxy Caching

Reverse Proxy caching technique allows caches to be deployed near the origin of the content to accelerate web traffic. Reverse Proxy caching mechanism enhances internet speed and performs proxy load balancing between multiple web servers. This technique permits traffic grooming and modification of *http* requests passing through reverse proxy server. Therefore, reverse proxy server are full fledged web servers with dedicated functionality of caching (Obraczka, 2000, pp. 1-10). Reverse Proxy caching reduces the load on congested web servers using an intermediate web cache between server and internet. Well configured reverse proxy server caching systems leads to significant bandwidth savings, server load balancing, perceived network latency reduction and guarantees higher content availability to the users.

2.3.3 Transparent Proxy Caching

Transparent Proxy mechanism intercepts http requests and reroutes them to the web cache servers therefore, "*transparent Proxy mechanism caches network traffic without*

user or browser configuration" (Feng, 2011, pp. 1-6). This technique allows filtering of http requests from all outbound Internet traffic; therefore reduce network latencies experienced over the network. This enables the web server to release network traffic load hence reduced user perceived response time (Teng, 2005, pp. 444-454).

2.3.4 Web Caching Schemes

Popularity-wise caching algorithm caches highly interactive streaming or live streaming which is a bandwidth intensive and consuming activity. This Popularity-wise Caching algorithm is designed to deal with arbitrary popularity distribution of media content. In regard to this, Popularity-wise Caching algorithm which only caches the most popular parts of all media objects; reduces both the startup latency of interactive requests and the backbone bandwidth required hence cost saving (Liu et al., 2004). However this approach does not address prefetching technique which also plays essential role in bandwidth optimization and reduction in network latency. Building a flexible web caching system is another approach in search of solutions in optimizing bandwidth. In this approach, the researcher shows architecture that uses combined web caching configurations. In this architecture, the researcher gives basic ideas for implementing a cooperative Web caching system using groups of http proxy servers which can therefore improve access to remote web objects regardless of the changes that might occur on the network environment. In this approach, the researcher developed a reliable and useful tool for simulation hence becoming a dependable tool for evaluation of Web caching architectures (Víctor et al., 2003). In regard to this, web prefetching technique is not featured. Soft Caching is another strategy used to optimize bandwidth and reduce high

network latencies. In soft caching technique, an image can be cached at one of a set of levels of resolutions. This improves the overall performance when combined with other cache management strategies that estimates the proximity of each web object, where the web object is stored and the appropriate resolution level demanded by the user or client (Rao, 2012, pp. 476-477). Many innovative network tools are currently available to control web traffic. Network-based Uniform Resource Locator filtering is widely used tool to detect and filter unnecessary web traffic. However, this network tool still suffers setbacks arising from high bandwidth consumption. In mitigation of this inefficiency in Network-based Uniform Resource Locator filtering (Feng, 2011, pp. 1-6) came up with multi-level counting bloom filter that uses cache to analyze results from a network server to accelerate web traffic, balance traffic loads and reduce bandwidth consumption.

2.3.5 Cache Replacement Policy

Semantic and Least Recently Used Web cache replacement policy is a paramount technique in caching. In this approach, Semantic and Least Recently Used Web cache replacement evicts documents that are less related to an incoming document or least recently used document which needs to be stored in the cache (Carter, 2009). This ensures that related documents are stored in the cache. In case the cache is full or less disk space to cache web documents, the replacement policy determines which line should be evicted from the cache to create space for the incoming cache hit. The primary objective of replacement policy is to shrink potential cache misses by evicting lines that will not be referenced frequently in the near future (Carter, 2009). This replacement policy, improves the existing replacement algorithms through analyzing the semantic content of the document and the recency of web documents therefore, ensures that caches

operate effectively (Geetha, 2009). However, this approach does not feature prefetching technique which plays a major role in improving network traffic efficiency.

2.3.6 Cache Configuration Management

"Caching configurations on a Field-Programmable Gate Array, which is similar to caching instructions or data in a general memory, retains the configurations on the chip so the amount of the data that needs to be transferred to the chip can be reduced therefore, Field-Programmable Gate Array acts a cache" (Li, 2000). If the size of the cache chip has more space capacity to retain caching configuration computations, the configuration cache management will determine when configurations should be uploaded and evicted to reduce the reconfiguration times in the chip (Li, 2000). Another model of Field-Programmable Gate Array is Partial Run-Time Reconfigurable. In this model, Partial Run-Time Reconfigurable loads and retains configurations that are required rather than reconfiguring the whole chip leaving the chip in previous consistent state. The Single Context Field-Programmable Gate Array allows the whole chip to be reconfigured hence the chip is overridden during the reconfigurations. In Single Context Field-Programmable Gate Array model, it apportions numerous computation configurations which are liable to be accessed in near future therefore reducing switching times. The overall reconfiguration overhead is the summation of the reconfiguration latency of the individual reconfigurations (Li, 2000).

2.3.7 Hierarchical Caching Scheme

Using Hierarchical Scheme and Caching Techniques for Content Distribution Networks is another strategy used to manage and optimize bandwidth using caching technique. The fundamental initiative behind Hierarchical Scheme architecture is to consent caches to

leverage between each other when web object request arrives while the corresponding receiving cache does not have that specific web object (Obraczka, 2000, pp. 1-10). In hierarchical scheme, child nodes caches queries the parent caches and while child nodes queries each other. This allows diffusion of information within the hierarchical scheme architecture down to the child nodes of the hierarchy (Obraczka, 2000, pp. 1-10). *"Content Distribution Networks architecture applies hierarchical web caching technology to Content Distribution Networks architecture"* (Yang, 2007, pp. 535-538). Content Distribution Network pushes content from originating server close to cache servers nearer to the clients. The Content Distribution Networks architecture improves significantly the response time of http requests resulting to reduced network latencies and traffic loads from the originating servers (Yang, 2007, pp. 535-538). With reduced network latency, it is evident that network http requests will response faster hence higher internet speeds connection. It is profound that this Content Distribution Network architecture ensures that bandwidth optimality is achieved.

2.3.8 Performance Comparison of Alternative Web Caching

Using Performance Comparison of Alternative web caching technique is a paramount method "used to improve the performance and scalability of the Web". Performance Comparison of Alternative web strategy ensures reliability and availability of web objects according to (Hassanein, 2000). This approach uses distributed cache cooperation, a technique for sharing web documents between caches allowing enhanced network improved performance. Performance Comparison of Alternative web caching strategy provides a shared cache to numerous clienteles to cache more web objects hence reducing network access delays. The alternative web caching technique saves bandwidth by

caching frequently user's *http* requests by redirecting *http* requests to cache servers where enough caching space is found (Hassanein, 2000). Alternative web caching assists local proxy servers caches when there is a cache miss in the local proxy server. The http requests are redirected to the alternative caching servers guaranteeing a cache hit.

2.4 Prefetching Technique

"Prefetching is a performance optimization technique that allows to bring back more than one type of objects into a single query" (Teng, 2005). Prefetching approach takes advantage of the spatial locality of web objects. It retrieves http requests in advance from remote servers in anticipation of user requests. This reduces the round trip taken to retrieve user's *http* request from a remote web server. According to (Teng, 2005)*"the prefetched http requests are very likely to be referenced in the client's subsequent requests will be part of the network latency that can be hidden from the client's consecutive requests".* The effectiveness of prefetching depends on predictability in users' web page accesses, performance, completeness of the algorithm and its precise accuracy for predictability. With the advent of World Wide Web growth, prefetching technique has become one of the most useful methods in reducing World Wide Web latencies. "Prefetching technique seeks to reduce the perceived latency by look-ahead" (Horng, 2009, pp. 1-8). With anticipation of web pages that a user will find in the near future, it is feasible to preload these web pages to the user before they are requested. The perceived latency can then be reduced to that, for fetching web pages from local disks or file servers on local networks. Prefetching technique prefetches web documents on proxy servers thus improving cache hit rate ratio hence faster *http* response time (Kaur, 2013, pp. 1878-1881). This approach increases hit rate of caching proxy and also improve the

accuracy of prediction thus faster response of web objects. When this technique of prefetching is combined with other values, there will be increased network traffic generated which can be also controlled (Kaur, 2013, pp. 1878-1881). Using only this prefetching technique will not achieve full benefits of bandwidth optimization hence partial outcomes.

2.4.1 Prediction Web Prefetching

Prediction by Partial Match is a commonly used technique in web prefetching. In this technique, prefetching decisions are made based on historical uniform resource locators in a dynamically maintained Markov prediction tree. In this model, the tree is dynamically updated with a variable height in each set of branches where a popular uniform resource locator will have the longest branches under its root and on the other hand, the less popular web objects will have shorter branches (Zhang, 2002). Additional optimizations in this model include linking directly a root node to duplicated popular nodes in a surfing path to give popular uniform resource locators more weight for prefetching. It also makes a space optimization after the tree is built to delete less popular web documents nodes (Zhang, 2002). This approach touches on web prefetching technique which will only achieve partial bandwidth optimality since web caching technique is not incorporated.

2.4.2 Instruction Prefetching

Instruction prefetching methods are analyzed using a cache performance model. Improvement in performance achieved by using an instruction prefetching method is classified into two factors: the number of cache misses reduced by prefetching and the average amount of miss penalty reduced by successful prefetches. In this approach the

efficiency of instruction prefetching methods is examined and analyzed based on a cache performance model comprising of a cache memory system configured using instruction prefetching method (Park, 2000, pp. 505-506). This method will only increase prefetches efficiency enhancing delivery of faster internet connection to the client. This technique does not address caching technique which is known to reduce internet latencies. Instruction prefetching using Basic block prediction is another technique used in prefetching. Basic block Instruction Prefetching technique employs a prefetches engine which issues prefetches instructions to achieve useful and early prefetches far enough in advance (Shyamala, 2008). This approach produces timely and accurate prediction results that can be utilized effectively hence improved timelines. Accurate prediction in prefetching leads to high percentage of reduction in cache misses thus enhances the number of cache hits.

2.4.3 Generalized Web Prefetching

Data Mining Algorithm for Generalized Web Prefetching is another approach used in prefetching web documents based on algorithms. This type of approach emphasizes on previous research findings done by (Shim, 1999, pp. 549-560). The research done by (Shim, 1999) based on proxy cache algorithms while (Nanopoulos, 2003) did research on generalized web prefetching algorithms. This approach assumed that a server-side proxy does the work as predictive prefetcher and the caching server in which its predictions hints are relayed to the client as well as caches web documents requested by the clients in the server-side proxy. The server side proxy cooperates with a prefetching engine to disseminate hints every time a client requests a web object from the server (Nanopoulos, 2003).

2.5 Web Proxying

2.5.1 Dynamic Objects Manager Proxy Architecture

Dynamic Objects Manager Proxy architecture is another approach used. In this Proxy architecture, it enables front-end web caching for dynamically generated web pages. That is, it provides methods for caching their generation process which can be accomplished by caching applications and back-end web content that are being used to create dynamic web documents. The main feature of Dynamic Objects Manager Proxy is the capability to cache the generation process of dynamic web pages instead of the pages themselves. In regard to this, caching the generation process of a dynamic web page translates to the caching of its components that forms part of cache generation process. These components include application programs that create the dynamic web pages, back-end database content, database queries generated during the process of applications' execution and query results that back-end database management produces (Veliskakis, 2005). The approach of Dynamic Objects Manager Proxy architecture only focuses on caching generation process thus prefetching technique which is imperative in achieving bandwidth optimality and low network latencies is left out.

2.5.2 Transparent Web Proxy

Research done by (Jia et al., 2005) on Optimal Replication of Data Object at Hierarchical and Transparent Web Proxies reveals that re-routing of *http* requests in order to increase hit ratio rate. In this approach, proxies are capable of intercepting users' requests and forwarding the requests to a higher level proxy if the requested data are not present in their local cache. The effectiveness of this transparent web proxy method mostly relies on the stability of the routing methods. If the routing method used is stable, the transparent

proxies' hit-ratio rate increases (Jia et al., 2005) et al. However, this approach is only limited to transparent proxies only. This approach does not feature the prefetching technique. It is notable that research done on transparent proxy web caching yields tangible results by caching non-cacheable web objects. Under this transparent proxy Web caching, http requests are intercepted and rerouted based on the web documents content. This mechanism makes configuration of caching easier and it also improves performance by rerouting non-cacheable http requests to bypass cache servers (Hassanein, 2000). This approach improves http requests response time but will not achieve its maximum optimality since prefetching technique was not incorporated.

2.5.3 Caching and Prefetching Integration

Integration of Web Caching and Prefetching algorithm is also another important technique. In this approach, the algorithm tries to integrates Web caching and Web prefetching in client-side proxies. It formulates a normalized profit function to evaluate the profit from caching an object. This normalized profit function considers factors like size, fetching cost, reference rate, cost and invalidation frequency of a Web object. It also exploits the effects caused by various web prefetching schemes (Teng, 2005, pp. 444-454). In this approach, it only exploits the client-side proxies leaving the server-side proxies and client's browser caching.

2.6. Latency Management

"Latency refers to any of several kinds of delays typically incurred in processing of network data" (Davison, 2001). A so-called low latency network connection is one that generally experiences small delay times, while a high latency connection generally suffers from long delays. Latency management is a strategy used in networking to control

and minimize unnecessary network transmission delays that could hinder content delivery in an effective way. *"Latency management is the key to understanding the root problems and solutions to many of the performance problems experienced in on today's broadband access networks"* (Society, 2012). With latency management policy, it is easier to root out inherent network paths that contain buffer overflows and traffic congestions consequently enhancing bandwidth overall throughput by eliminating network latencies between the transport control protocols. Latency management strategy assists in removing propagation delays, routing, switching queuing and buffering issues. It is of primary importance to note that latencies will always be present in any network, but it can be controlled and managed (Rash, 2010).

2.7 Query Optimization

"Query optimization is a process of producing an optimal query execution plan which represents an execution strategy operating within set of resource constraints" (Mithani, 2016). The primary goal of query optimization is to produce efficient execution strategies for declarative queries (Galindo-Legaria, 2008, pp. 1-8). Queries that need optimization arises from data driven web based applications that uses mysql and structured query language queries to retrieve and store information. Query optimization is achievable through utilization of cost-based query which transforms mysql or structured query language queries in web based applications to yield optimized results. These high level queries can be transformed using heuristic optimization and cost-based query optimizations approaches to reduce network traffic loads within a network infrastructure suffering from high latencies therefore, saving substantial bandwidth. Query optimization technique augment performance of declarative queries in objected oriented database

systems therefore, query optimization is an absolute necessity in database management systems. The main objective of query optimization is to generate efficient execution approach for declarative queries, reduce response time of the query and optimal execution time (Galindo-Legaria, 2008, pp. 1-8). Query optimization in relational database management systems enormously depends on cost estimation of the query to select the best feasible optimal execution plan. *"Query cost estimation relies on cardinality estimations of various execution plan*s *during query optimization"* (Bruno, 2002, pp. 263-274). There are two types of query optimization in database management systems; Cost-based and heuristic –based query optimization.

2.7.1 Cost-Based Query Optimization

Cost-based query optimization strategy takes number of execution plans and selects one execution with optimal cost (Mithani, 2016, pp. 1-4). Query optimization cost functions are just estimates and not exact cost functions therefore; the optimization might select a query execution plan that is not the optimal one. To effectively achieve this, query optimizers estimate the cost of each execution plan before choosing the best optimal query execution plan (Filho, 2008, pp. 1-5). The drive behind cost-based query optimization approach is to come up with the best optimal execution plan that utilizes minimal network resources to achieve the desired output. Cost-based query optimization is considered to have met standards for optimization when query cost estimation is accurate and logically consistent with least cost execution plan (Barwal, 2014, pp. 841-852). Cost-based query optimization exploits query statistics, indexes and the data distribution to make execution plan choice. Path indexes provide an efficient access to complex objects since a condition on a path expression is evaluated by use of indexes

without fetching any database objects further (Mithani, 2016, pp. 1-4). The different attributes and constraints of the cost-based query optimization makes Cost-based optimization process expensive, but valuable for queries with bulky datasets since its space complexity remain same.

2.7.2 Heuristic Query Optimization

Heuristic query optimization transforms the query-tree by using a set of rules that naturally enhance query response time and performance (Bruno, 2002, pp. 263-274). Heuristic query optimization performs projection of query execution plan as early as possible and keeps projection attributes and constrains on the same relation. This allows query execution to compute unary relational expression by reducing number of tuples and attributes. Heuristic query optimization eliminates non-optimal execution plans and selects only best optimal execution plans hence more efficient technique than cost-based query optimization technique. This can be attributed to transformation of query trees through series of alterations which in turn reduce execution time. Moreover, heuristic query optimization federates queries in execution plans to achieve query optimization process resulting to faster response time, higher network throughput and saves bandwidth.

2.8 Theoretical Framework

The concept of network utilization and has been researched extensively by many researchers. (Kießling et al., 1998, pp. 308-318), came up with a model to test Quick-Combine algorithm on visual retrieval of multimedia images and videos from database systems. In this model, HERON-middleware contains query engine which does querying of the datasets from databases while the combining engine retrieves visual images from a

ranked set of image objects as a query result from universal database systems. This framework is based on the scheme that multimedia objects are often stored redundantly to support broadest system access for diverse clients from heterogeneous environments. Therefore, HERON-middleware architecture can be used extensively in universal database systems to implement self-tuning and adaptive digital image archives (Wagner, 2005). Therefore, enhances utilization and optimization of network resources thus improved network performance.

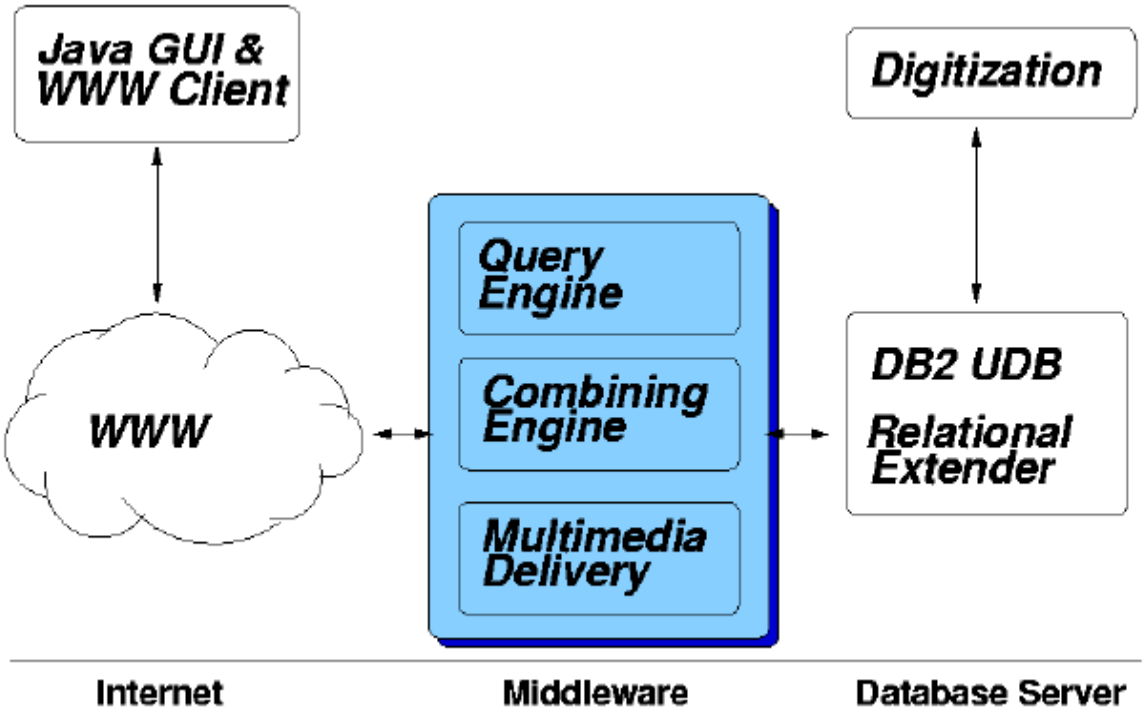


Figure 1.1: Architecture of the HERON-system

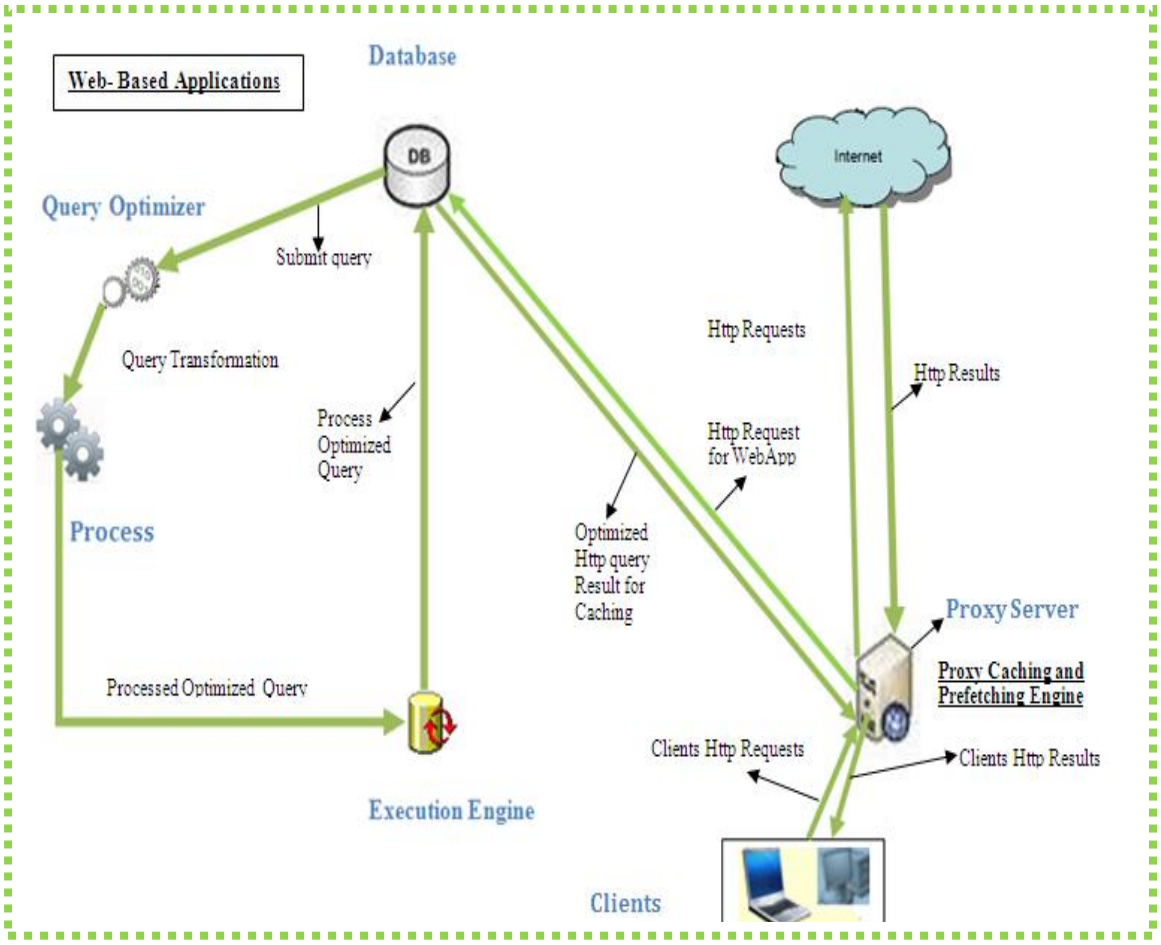
Architecture of the HERON-system (Source: (Balke, 2000, pp. 1-6)

2.8.1 Application to the Study

From the HERON-system architecture, the researcher applied this theoretical framework to come up with its own conceptual framework as illustrated in figure 1.2 to support the scheme of optimizing network and network utilization performance at Kabarak University.

2.9 Conceptual Framework

From the discussion on HERON-middleware architecture as illustrated in figure 1.1 of this research study, a conceptual framework was designed to help identify areas of research relevance to the current research study. This framework was based on a review of the research on HERON-middleware architecture. This model incorporates optimization techniques that are used in network utilization and performance. Developing from the research questions, other optimization techniques were acknowledged in the literature as being fundamental to this research study. A review of these optimization techniques was essential in order to answer the research question and to meet the research objectives stated.



Research Boundary Conceptual Framework *(Source: Current Research)*

Figure 1.2: Conceptual Framework

2.10 Computational Model

The hybrid algorithm below guided the researcher in implementing the conceptual framework in figure 1.2 in regards to conceptualizing the idea. The illustration in figure 1.2 above reflects transformation of data driven queries from web based applications and other http requests from users bypassing through proxy server to World Wide Web.

Text box 1.1: Hybrid Algorithm Computational Model

Let us assume the variables

O_q =Optimized HTTP query from web based applications

Rn=Other HTTP requests from clients

S_1 =Space available for caching

S_2 =Space available for prefetching

If Time To Live (TTL) does not expire then

Check space available for S_1 and S_2

If space is enough then

Cache and prefetch O_q

Update S_1, S_2

Else

Evict HTTP requests NOT frequently accessed

Exit

If Time To Live (TTL) does not expire then

Check space available for S_1 and S_2

If space is enough then

Cache and prefetch Rn

Update S_1, S_2

Else

Evict HTTP requests NOT frequently accessed

Exit

End.

Hybrid Computational Model *(Source: Balk* (Junho, 1999, pp. 549-562)*).* The hybrid computational algorithm model in text box 1.1 above provides insights on how squid proxy caches and prefeches http access logs. Squid proxy server, logrotate access logs files by compression and removal to free more caching and prefeching space. It evicts *http* requests which are not frequently accessed replacing them with new http requests. The hybrid algorithm computational model above guided researcher in monitoring network usage at Kabarak University.

2.11 Network Measurement and Analysis Tools

Cacti is an open source web-based network monitoring and graphing tool designed to harness the power of Round-Robin-Database Tool data storage and graphing functionality. Cacti integrate cache and memory access time, cycle time and leakage therefore, instill user confidence in tradeoffs between times, area, leakage which are based in assumptions. Cacti provide a comprehensive and high-level visibility to entire Local Area Network, Wireless Network and Wide Area Network. Nagios tool is open source software under General Public License v2.0. Nagios monitors entire network performance to identify critical network breakdowns in advance and mitigate them before affecting end users (Barth, 2008). Nagios provides instant alerts on status of network performance hence end-to-end network visibility. SmokePing is an open source web-based latency measurement tool. SmokePing utilizes Round-Robin-Database Tool to store and display latency, latency distribution, packet losses and generate statistical graphs and charts. SmokePing captures time-series data (successive measurements made over a time interval) to probe servers for any form of latency. Unifi Controller provides the necessary platform to manage wireless access points easing management of wireless network traffic.

2.12 Summary

This chapter presented the essential facts of works which was previously done in regards to in network utilization strategies and its attempts to search for solutions. We presented the concepts associated with strategies used in network utilization and performance as referred in the literature, including bandwidth management and optimization, query optimization, caching, prefetching and latency management. Chapter three of this research study presents research methodologies used in this study.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

The foundation of this chapter have been set out clearly as prescribed in chapter one where problem statement, aim and set of objectives are defined. This chapter describes the design of the research study and research methodology used to conduct the research at the fieldwork. "*Methodology is defined as a collection of methods, procedures, techniques and standards that defines an integrated synthesis of engineering approaches to the development of a product"* (SEI, 1995). This research study takes quantitative research approach. "*Quantitative research approach explains phenomena by collecting numerical data that are analyzed using mathematically based methods (in particular statistics)"* (Martha, 2005). This chapter discusses the research design, system design, study population; study sample and sampling method, data collection instruments, data procedures and finally the data analysis and presentation methods used in this study.

3.1 Research Design

Research Design is the plan and structure of investigation used to obtain evidence and answer research objectives (Mugenda O. , 1999). According to (Grove, 2008) research design is *"a blueprint for conducting a study with maximum control over factors that may interfere with the validity of the findings".* Therefore, research design is a plan or process showing how the problem under investigation will be solved. The researcher used experimental research design approach. Experimental research design approach is based on experimentation or observation to answer the specific research objectives. In order to empirically examine this, a survey was conducted on 192 full-time staff and students focusing on the following variables: perceived quality of service, latency management,

bandwidth optimization, Query optimization, proxy load balancing, end-to-end network visibility, content filtering and ICT policy. These variables were then subjected to network measurement and analysis tools which include Cacti, Nagios, Smokeping and the numerical data then analyzed using statistical procedures (Laban, 2010). In empirical research approach results can be replicated. It is also paramount to note that empirical research approach yields quantitative data which was analyzed using statistical procedures. The data collection method has been considered because it narrows down a very broad field of research that involves investigation of a process thus enabling the researcher to answer the research questions systematically and comprehensively. Therefore, allowed for intensive experimentation and observation of a particular setting.

3.2 System Design

3.2.1 Design Model

Prototyping system design approach was found to be the most suitable method for this research study. A prototyping methodology is a process which allows researchers to create small portions of the solution in a systematic manner and make necessary refinement before the final solution is delivered. There are three categories of prototyping namely exploration, experiment and evolution. In exploration prototyping approach, it entails clarification of user requirements thus assist the developers to gain insight to user problems and tasks. Experimental prototyping approach gives the users the space to evaluate the feasibility of the system when requirements are specified. Evolutionary prototyping approach allows flexibility and response to agile process where user changing requirements are taken care of (Chen H. , 2016, pp. 7-12). Experimental prototyping approach has been selected because it has the ability to perform experiments

and evaluate outcome results therefore, saves time and resources. Experiments on network usage and network traffic pattern analysis were performed based on the following variables: query optimization, latency management, bandwidth optimization, proxy load balancing and network performance monitoring.

3.3 Study Population

Study population was only limited to the regular students and members of staff who are working on fulltime basis. There are 886 students in undergraduate and Cisco programmes who are both in the Main Campus, Nakuru Town Campus and Nairobi Town Campus therefore, formed part of the study population sample. The regular students on fulltime basis were chosen to draw up a sample from because of their accessibility and significant number of respondents in both the campuses at Kabarak University. Students samples were drawn from school of Business, IT , Law and Cisco academy across the study levels.

Sample was drawn up from 75 fulltime members of staff to the represent the study population. The staff sample was drawn from the following staff member groups: Management, Teaching staff and IT staff. Staff samples were mainly comprised of respondents who have adequate knowledge on network utilization and performance strategies. After prospective respondents were identified, the researcher sent email invitations containing consent and web based questionnaire to be filled after reading the consent. The respondents were informed the right of voluntary participation.

3.4 Study Sample and Sampling Procedure

Sampling involves the process of selecting a number of individuals from a population to be studied in such a way that the individuals selected represent the large group from which they were selected (Mugenda O. A., 2003).The main objective of sampling is to approximate some pointer in the entire population and obtain the results from part of the population that can be generalized to the entire population accurately.

3.4.1 Sampling Method

Stratified random sampling which is a probability technique was utilized in this research study to draw up a sample of participants who provided adequate information for this research study. *"Stratified random sampling is a probability sampling technique where the researcher separates the entire population into different strata, then a simple random sample is selected from each stratum"* (Daniel, 2011, pp. 125-174). The rationale behind this sampling approach was to allow researcher to collect samples from diverse backgrounds and strata in order to get more varied data as well as unbiased sample population. The researcher purposively selected participants who were perceived to be information rich and appropriate for the research study. In this research study, the researcher emailed the questionnaires to respondents sampled for this researcher study.

3.4.2 Sampling procedure

Stratified random sampling was used to obtain population sample from each population category stratum as show in Table 1.1 below. According to (Patten, 2004), stratified random sampling utilizes the same percentage of participants but not the same number of participants to draw up population sample size from each stratum. Samples of 20% were drawn up from each stratum to represent the entire population. Based on this scenario, the

researcher considered 20% of the entire population of 192 randomly selected staff and students in obtaining sufficient representative sample since time frame required and material resources needed for larger population sample size was inadequate. The rationale used to determine this population sample size was adopted from a table of recommended sample sizes (n) for populations (N) with finite sizes developed by Krejcie and Morgan and adapted by (Patten, 2004). The population sample size targets mainly respondents with basic knowledge in Information Technology and frequent internet users. The researcher sought the assistance from systems administrator to identify potential respondents through corporate email groups. The researcher emailed consents to the respondents participating in the research study. The sample was then obtained as follows:

3.4.3 Target Population Sample

Table 1.1: The Target Population

Category	Number	20% Sample	TOTAL
Students	886	177	177
Staff	75	15	15
Total	961	192	192

Source (Kabarak-University, 2011)

3.5 Data Collection Methods

The data collection methods that were used to gather information from respondents include questionnaires, interviews and observation.

3.5.1 Questionnaires

Web based questionnaires were used as one of the research instrument to collect data from the respondents sampled from the entire population for control group. The web based questionnaires were designed using Google docs with standardized answers that make it easy to compile data. The published link of the Web based questionnaires was then emailed to the respective respondents by researcher. The emailed questionnaire consists of a link to the Web based questionnaire which can be authenticated by respondents using respective email addresses. When a respondent clicks on the hyper link provided and logging into the into the Google docs then, the participant hereafter agreed to participate in the research study. This approach was preferred because web based questionnaires can be administered to a large number of the respondents thus saves time and costs for the researcher. Web based questionnaires allows the respondents to complete the questionnaires at their own pace and time therefore, the most suitable method to get the respondents opinions and personal experiences from the sampled population.

3.5.2 Interviews

The researcher utilized Computer Assisted Personal Interviewing. Computer Assisted Personal Interviewing is a form of personal interviewing, where the interviewer brings along a laptop or tablet to enter the information directly into the database instead of completing a questionnaire. Computer Assisted Personal Interviewing was used gather data from the respondents sampled from the staff management from the sampled population. Computer Assisted Personal Interviewing allowed the researcher to examine specific detailed issues. This approach allowed the researcher to acquire more precise

information, answers and opinions from the respondents. To minimize biased samples from the study, the researcher only focused on the set objectives of the study when interviewing the respondents. Respondents sampled from the management provided essential data on enforcement ICT policies and investment on IT resources therefore, formed part of the research study.

3.5.3 Observation

'Observation involves recording the behavioral patterns of people, objects and events in a systematic manner'' (Schools, 2014). Structured observation was used as a data collection method in this research study. 'In structured observation, the researcher specifies in detail what is observed and how the measurements are recorded" (Schools, 2014). Therefore, structured observation was used to record the behavioral patterns of network usage and network traffic analysis from web objects and *http* requests in real-time. These recordings were then analyzed using SPSS.

3.6 Pre-Testing

Pre-testing was conducted on the data collection methods to discover any ambiguous entries and to identify setbacks in the tools and instruments used to collect data. Pre-testing conducted by the researcher cross-checked the responses from the questionnaires and results from the experiments. The results were pre-tested in production systems in Kabarak University and results recorded for the cross-validation.

3.7 Ethical Considerations

The researcher followed strict ethical guidelines that involve anonymity, confidentiality and voluntary participation of the respondents from the sampled population. The researcher sought informed consent from Kabarak University before commencing the

research study. The researcher sent emails to the prospective respondents and those who agreed to participate; informed consent was sought from them. The respondents were informed of the confidentiality and anonymity of the research instruments used collect data in this research study. The participants were not obliged to provide any information that could have revealed their identities to address any ethical concerns that might be raised by the respondents during the research study. Following the approval by Kabarak University to commence the research study, the researcher sought informed consent with the National Council for Science and technology. Information collected from the respondents was treated with confidentiality and anonymity of the respondents that participated in the study.

3.8 Data Analysis

Data collected using questionnaires, interviews and structured observations were sorted, classified, coded, edited and data then analyzed quantitatively according to the objectives of the study using Statistical Package for Social Scientist. The data were presented in form of frequency distribution tables that facilitates description and explanation of the study findings in a systematical manner. Finally, the findings were then analyzed in terms of the literature and conclusions drawn from the researched study.

3.9 Delimitations

This research study does not assert to be a comprehensive study of techniques for optimizing network utilization and performance practices in institutions of higher learning in Kenya. Relatively, it is a personal initiative to research techniques for optimizing network utilization and performance given the limitations of time and budget. It is important to note that, the study does not assert the extent of authoritatively, rather than researcher’s interpretation.

3.10 Summary

This chapter described the research design and methodology of the research study and how the research was conducted. The rationale behind the research design is to capitalize on the answers that validate research questions in the study. Quantitative research approach was used to attain this primary objective. The researcher collected data by using online questionnaire for all respondents sampled in this research study. Moreover, proxy server logs, and firewall logs formed part of the collected data. This chapter sought to explain the delimitations of this research study. Chapter four presents data analysis and discusses the findings of the research study.

CHAPTER FOUR

ANALYSIS AND DISCUSSIONS

4.0. Introduction

This chapter reports on analysis of data and discussions of the research findings carried out on network utilization and performance at Kabarak University. The research findings of this study were steered by the research questions and results visualized and summarized for easy interpretations. Variables that have been set in Likert scale of 1- 3 in this chapter, the subsequent responses under *strongly agree* and *agree* are combined to indicate total agreement, while the responses under *strongly disagree* and *disagree* are combined to indicate disagreement for ease of interpretation of results. The data collected from the fieldwork were analyzed to ascertain the need for optimizing network utilization and performance.

4.1 Response rate of Questionnaires

Data were obtained from two set of questionnaires: student questionnaire and staff questionnaire as illustrated in Table 1.2.

Table 1.2: Questionnaire Categories Summary

Variable	Frequency (*f*)	Percentage (%)
Questionnaires received from Students	177	92.2
Questionnaires received from Staff	15	7.8
Total	192	100.0

The pie chart below summaries percentage values for the table 1.2.

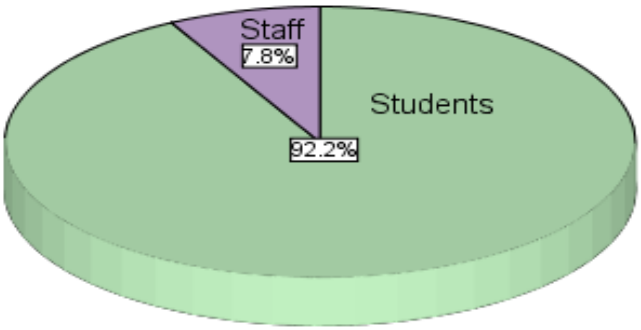


Figure 1.3: Questionnaire Summary Responses

The results and findings of this research study are divided into four segments. The first segment discusses methods of data analysis and presentation of data. The second segment deals with demographic information of the respondents. The third segment presents the analysis and discussion of data from the questionnaires administered to the respondents. The fourth segment presents a summary of the results of this research study.

4.2 Methods of Data Analysis and Presentation of Data

Inferential statistical analysis was used to analyze the population sample. All respondents answered all of the questions and therefore percentages reported correspond to the total number of students and staff answering the individual questions in students and staff questionnaires respectively. Results were analyzed and presented in form of frequency tables and graphs with appropriate discusses. The frequency distribution of each variable was scrutinized to ascertain the numerical value which represents the total number of responses for a variable under research study. The results of this research study envisaged

the search for variables and correlation of data. The statistical significance of relationships among selected variables was determined using the Chi square test. The level of significance was set at 0.05.

4.3 Student Sample

This section describes the analyses and discusses of the research findings from the student's questionnaire (see Appendix B) of this study as described in section 3.5.3 of the research design. The research findings in this section relate to the research questions that guided the study.

4.4. Demographic Information

In section 4.5, the demographic data of the respondents gathered from the web based questionnaire is presented and analyzed to illustrate the distribution of the respondents by gender, age, level of study, designation and department. This set of demographic data is paramount to the research study to determine if these demographic variables of the sample have any bearing on the analysis or in anyway influence the research findings.

4.4.1 Demographic Study Variables

Table 1.3 below, presents set of demographic variables for student questionnaire to assess if demographic variables bear any influence on the research findings of this study.

Table 1.3: Students Respondents by Gender

Gender	Frequency (*f*)	Percent (%)
Female	75	42.4
Male	102	57.6
Total	177	100.0

Table 1.3 above illustrates the distribution of the student's survey questionnaire respondents according to gender. Participants were asked to indicate their gender by placing a tick on the checkbox next to the relevant option provided (Male or Female). From Table 1.3, it shows that the majority of the respondents were male representing (57.6%) of while (42.4%) were female. The fact that there were more male in the student's survey questionnaire sample than female is not by design; and these gender imbalances attest to the fact that Information Technology (IT) courses is a male dominated profession although more females are joining this profession based on the current trends (Sue Botcherby, 2012).

Table 1.4: Test Results of School Verses Gender Cross Tabulation

Gender	School				Total Respondents
	CISCO ACADEMY	BUSINESS	LAW	IT	
Female	39 Respondents (22.0%)	11 Respondents (6.2%)	4 Respondents (2.3%)	21 Respondents (11.9%)	75 Respondents (42.4%)
Male	29 Respondents (16.4%)	8 Respondents (4.5%)	6 Respondents (3.4%)	59 Respondents (33.3%)	102 Respondents (57.6%)
`Total	68 Respondents (38.4%)	19 Respondents (10.7%)	10 Respondents (5.7%)	80 Respondents (45.2%)	177 Respondents (100%)

Chi-square Test *p*-value = 0.001

*(A *p*-value of <0.05 denotes significance)

In this research study, all schools sampled from the entire population were represented, making the responses a reasonable cross-section of the population sample. Table 1.4 above shows the correlation between gender and school. In this table 1.4, the correlation between gender and school was statistically significant ($p<0.05$), denoting that there were more responses from male respondents compared to female respondents from the sampled schools. Based on this statistics it is evident that Information Technology (IT) courses are male dominated field (Nancy, 2001). This is consistent with the findings of this study, which indicates that majority of the respondents were male doing IT related courses representing (57.6%) while (42.4%) were female. The gender differences in this research study attribute to students attitude towards certain courses in institutions of higher learning. The figure 1.4 below summarizes results for the table 1.4.

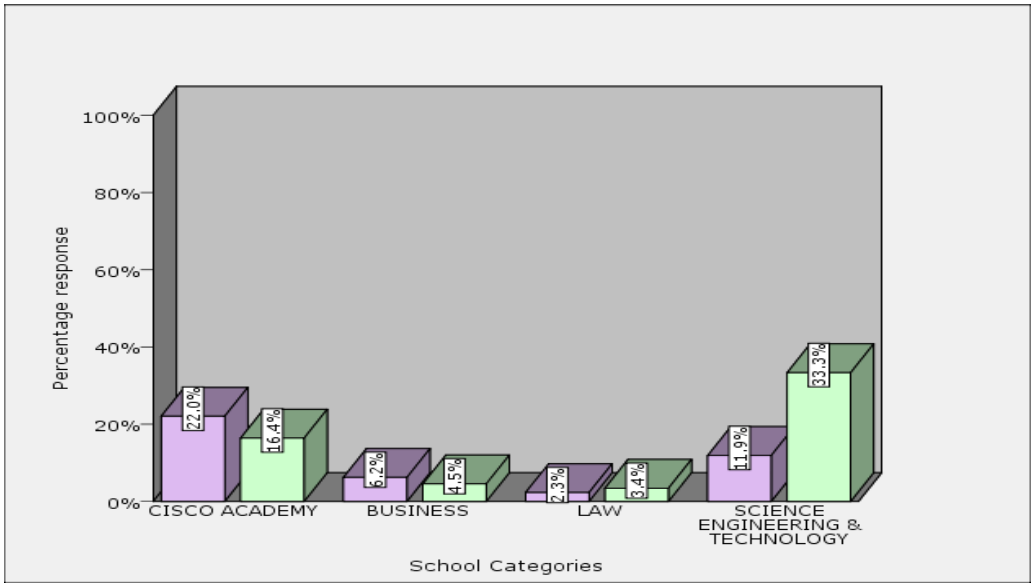


Figure 1.4: Summary Results of Cross Tabulation between School and Gender

Legend

Female

Male

4.4.2 Distribution of Respondents by Age

Table 1.5 below, describes the distribution of the student's survey questionnaire respondents according to their age bracket as shown below.

Table 1.5: Students Respondents by Age

Age	Frequency (*f*)	Percent (%)
0-18 Years	1	0.6
19-30 Years	154	87.0
31-45 Years	22	12.4
>45 Years	0	0.0
Total	177	100.0

Respondents were asked to indicate their age bracket appropriate to them (refer to Appendix B) in ranges of (0-18 years), (19-30 years), (31-45 years) and age greater than 45 years. Out of 177 responses, (87.0%) of the respondents were in the 19-30 years age category and constituted the size of the sample. This denotes the interest and desire for education among the youth. Another reasonable explanation of these results could be that the survey questionnaire administered resonated well in students with younger age than in older students. This further proves that most of students in institutions of higher learning are relatively young as illustrated in the table 1.5 above. (12.4 %) of the respondents were within the age bracket of (31-45 years). This demonstrates the energy and desire to achieve more among people above thirty one years in quest for knowledge and academic progression in institutions of higher learning. Only (0.6%) of the respondents were below the age of nineteen years. This indicates that majority of students in institutions of higher learning are generally above eighteen years.

4.4.3 Association between Age and School

Table 1.6: Test Results of School Verses Age Cross Tabulation

Age (Years)	School				Total Respondents
	CISCO ACADEMY	BUSINESS	LAW	IT	
0-18	1 Respondents (0.6%)	0 Respondents (0.0%)	0 Respondents (0.0%)	0 Respondents (0.0%)	1 Respondents (0.6%)
19-30	62 Respondents (35.0%)	15 Respondents (8.5%)	8 Respondents (4.5%)	69 Respondents (39.0%)	154 Respondents (87.0%)
31-45	5 Respondents (2.8%)	4 Respondents (2.3%)	2 Respondents (1.1%)	11 Respondents (6.2%)	22 Respondents (12.4%)
>45	0 Respondents (0.0%)	0 Respondents (0.0%)	0 Respondents (0.0%)	0 Respondents (0.0%)	0 Respondents (0.0%)
`Total	68 Respondents (38.4%)	19 Respondents (10.7%)	10 Respondents (5.7%)	80 Respondents (45.2%)	177 Respondents (100%)

Chi-square Test *p*-value = 0.536

*(A *p*-value of >0.05 denotes non-significance)

The table 1.6 above shows the correlation between age and school. The results from the table 1.6 showed mixed results exist between age and respondents attitudes towards the sampled schools. In table 1.6, the correlation between age and school was statistically not significant since the p-value of 0.536 is greater than the accepted conventionally significance level of 0.05 (i.e. $p<0.05$)

4.4 Bandwidth Management and Optimization

4.4.1 Average Hours spent on Internet

Table 1.7 below summarizes the findings from this study on average number of hours spent on internet per week by the sampled respondents. The average hours have been set in variable ranges as illustrated in table 1.7 below.

Table 1.7: Average Number of Hours spent on Internet per Week

Average hrs per week	Number of Respondents	
	Frequency (*f*)	Percentage (%)
0-9	100	56.5
10-19	11	31.1
20-29	55	6.2
30-39	6	3.4
40 +	5	2.8
Total	177	100.0

Respondents were asked average hours they spend on internet per week. The average hours were provided in ranges as shown in the table 1.7 above. Out of 177 respondents, 100 respondents representing (56.5%) spent between 0-9 hours per week of their time on internet indicating that majority of the respondent's at least spend significant amount of time on internet as demonstrated in the table 1.7 above. There were considerable 11 responses from respondents spending average of 10-19 hours per week representing (31.1%). This confirms that there is a growing tendency among the respondents on the time spent on internet due to availability of portable devices, increased network connectivity and coverage. Furthermore, 55 respondents (6.2%) reported that they spend 20-29 hours per week on internet. Moreover, 6 respondents (3.4%) reported that they spend 30-39 hours on internet per week. Finally, 5 respondents (2.8%) reported that they spend more than 40 hours on internet per week. The Figure 1.5 below summarizes the findings from this study on average number of hours spent on internet per week.

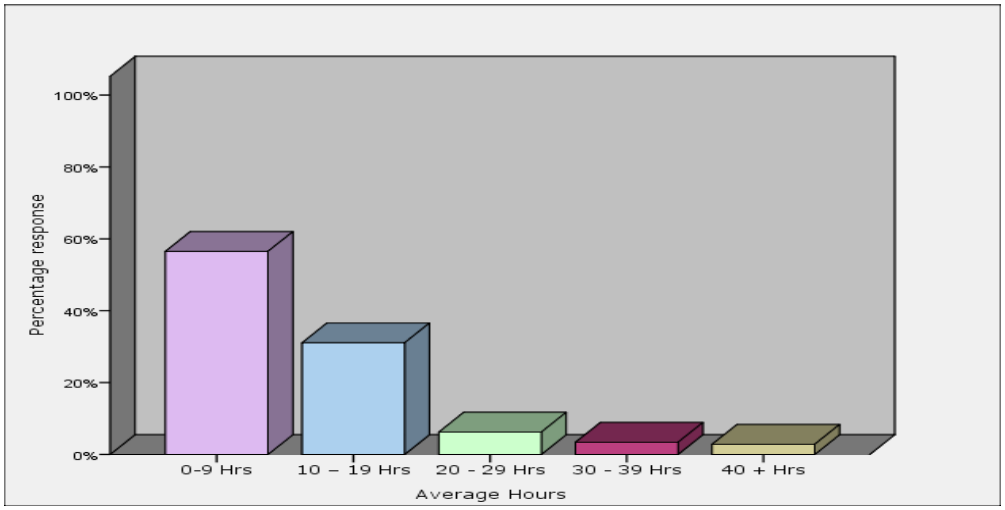


Figure 1.5: Average Hours per week Spent on Internet

4.5.2 Sites Popularity

Respondents were asked average hours they spend on popular sites per week. The sites were sampled based on most frequently accessed sites with the assistance of proxy server access logs. Table 1.8 below summarizes the findings from this study on how the sampled respondents spend their time on internet sites below in average hours. The average hours have been set in variable ranges as illustrated in table 1.8 below.

Table 1.8: Average Hours Spent on most Popular sites per Week

Hours	Kabarak Website (student portal)		Search Engines		Social Networks		Academic Research		General Browsing		Others sites	
	f	*Percent (%)*	F	*Percent (%)*	*f*	*Percent (%)*	F	*Percent %*	F	*Percent %*	*f*	*Percent %*
0-9	130	73.4%	36	20.3%	37	20.9%	120	67.8%	74	41.8%	88	49.7%
10 – 19	41	23.2%	101	57.1%	100	56.5%	32	18.1%	65	36.7%	77	43.5%
20 – 29	6	3.4%	25	14.1%	32	18.1%	11	6.2%	21	11.9%	7	4.0%
30 – 39	0	0.0%	8	4.5%	5	2.8%	10	5.6%	9	5.1%	1	0.6%
40+	0	0.0%	7	4.0%	3	1.7%	4	2.3%	8	4.5%	4	2.3%
Total	177	100.0%	177	100.0%	177	100.0%	177	100.0%	177	100.0%	177	100.0%

Kabarak Website (Student Portal)

Respondents were asked average hours they spend on Kabarak website and its sub-sites. Out of 177 respondents, 130 respondents (73.4%) reported that they spend an average of 0-9 hours on Kabarak website and its sub-sites. This indicates that majority of respondents' at least spends some time on Kabarak website and it is sub-sites as demonstrated by the results in the table 1.8. This can be attributed to respondents accessing the student portal and conference portal only on need to need basis exhibiting

high level of user interaction at peak times and fewer hours spent on the site during off-peak period. 41 respondents (23.2%) reported that they spend an average between 10-19 hours on Kabarak website and its sub-sites while 6 respondents (3.4%) reported that they spend an average between 20-29 hours on Kabarak website and its sub-sites. There were no reported respondents spending average of 30-39 hours or greater than 40 hours on Kabarak website and its sub-sites.

Search Engines

Searching is one the most frequent online activity in networking space among the respondents sampled. “With the advent of the Web and search engines, online searching has become a common method of obtaining information” (Chen Y.-M. K., 2013). Respondents were asked average hours they spend using search engines while seeking information. 36 respondents (20.3%) reported that they spend average time of 0-9 hours per week on search engine sites while 101 respondents (57.1%) reported that they spend average time of 10-19 hours per week. This depicts the intensity of respondents to satisfy their information needs through search engines. Furthermore, the percentage of internet users who use search engines has been steadily rising simply because most users are in consensus that they find what they are looking for when using search engines according to (Purcell, 2012). 25 respondents (14.1%) reported that they spend average time of 20-29 hours per week on search engines whilst 8 respondents (4.5%) reported that they spend average time of 30-39 hours per week on search engines respectively. Only 7 respondents (4.0%) reported average time greater than 40 hours per week on search engines. This demonstrates that most online activities start with search engines.

Social Networks

Social networks are the fastest growing segment and have remained a dominant category in most popular sites. Respondents were asked average hours they spend on social sites. From table 1.8 above each category sampled, recorded at least a response. Table 1.8 shows that respondents sampled from the entire population spend more hours on social networks with increased frequency than any sites. Social networks exhibit outstanding levels of user interaction. Out of 177 respondents, 37 respondents (20.9%) reported that they spend average time of 0-9 hours per week on social networks while 100 respondents (56.5%) reported that they spend average time of 10-19 hours per week on social networks respectively. This is a pointer to the fact that there is higher adoption and usage of social sites among the respondents. Moreover, with advent of increased connectivity, coverage, and new set of portable devices like smart phones have contributed to the current statistics where respondents spend longer times in social sites. 32 respondents (18.1%) reported that they spend average time of 20-29 hours per week on social networks whilst 5 respondents (2.8%) reported that they spend average time of 30-39 hours per week on social networks respectively. Only 2 respondents (1.7%) reported average time greater than 40 hours per week on social networks. The statistics shows that there is a steady increment in number of hours respondents spent on social sites as illustrated by statistics in table 1.8. This demonstrates how a social platform has remained top of the most accessed sites with many users spending more hours than any other sites (Purcell, 2012).

Academic Research

Academic Research sites have attracted less attention and usage among the respondents sampled with low online activity margins in hours spent. Respondents were asked average hours they spend on academic research sites. From the table 1.8 shown above, out of 177 respondents, 120 respondents (67.8%) reported that they spend average time of 0-9 hours per week on academic research sites. This demonstrates that majority of the respondents spends minimal time on academic research sites. 32 respondents (18.1%) reported that they spend average time of 10-19 hours per week on academic research sites while 11 respondents (6.2%) reported that they spend average time of 20-29 hours per week on academic research sites respectively.

Based on statistics in table 1.8, it portrays a shrinking number of researchers as confirmed by number of hours spent on academic research sites. 10 respondents (5.6%) reported that they spend average time of 30-39 hours per week on academic research sites while 4 respondents (2.3%) reported that they spend average time greater than 40 hours per week on academic research sites respectively. The statistics from table 1.8 above shows the extent of decline in the number of hours spent on academic research work. This can be attributed to the current generation of learners spending fewer hours on academic research work. It is evident that the current learners of today has a tendency of spreading themselves thin by engaging in more extraneous activities rather than academic work hence decline in number of academic research works.

General Browsing

Respondents were asked average hours they spend on general browsing. Out of 177 respondents, 74 respondents (41.8%) reported an average time of 0-9 hours on general browsing per week while 65 respondents (36.7%) reported an average time of 10-19 hours on general browsing category per week. Moreover, 21 respondents (11.9%) reported an average time of 20-29 hours on general browsing per week whilst 9 respondents (5.1%) reported an average time of 30-39 hours on general browsing per week. Only 8 respondents (4.5%) reported an average time greater than 40 hours per week on general browsing. From the table 1.8 above, significant number of respondents spends reasonable time in general browsing. This can be attributed to respondents either accessing their emails or accessing hierarchy of websites based on user's preferences.

Others

Respondents were asked average hours they spend on other sites. Out of 177 respondents, 88 respondents (49.7%) reported an average time of 0-9 hours per week in other sites while 77 respondents (43.5%) reported an average time of 10-19 hours per week in other sites category. 7 respondents (4.0%) reported an average time of 20-29 hours per week on other sites while only 1 respondent (0.6%) reported an average time of 30-39 hours per week on other sites. 4 respondents (2.3%) reported an average time greater than 40 hours per week on other sites. Figure 1.6 below summarizes the results of table 1.8.

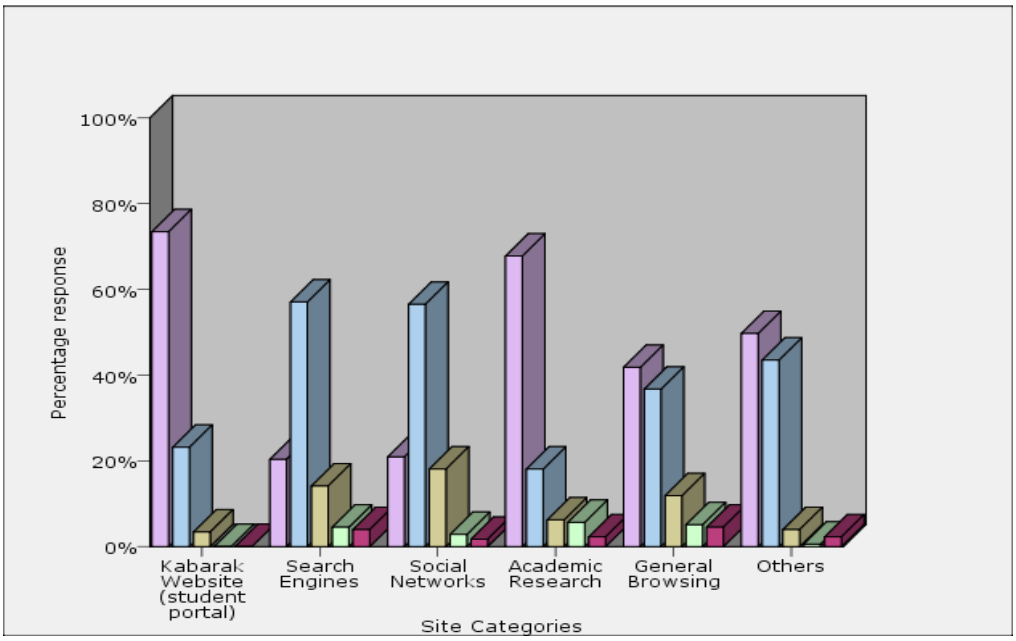


Figure 1.6: Average Hours per Week Spent on most Popular Sites

Legend

0-9 Hrs 20-29 Hrs 40+ Hrs

10-19 Hrs 30-39 Hrs

4.5.3 Bandwidth Management Strategies

With increased network connectivity and more bandwidth demands to accommodate progressively complex set of data traffic justifies the need for bandwidth management. Bandwidth management strategies enable network and system administrators to identify traffic types, user's preferences and critical applications on the network. This enables system administrators to prioritize network traffic effectively thus reducing network traffic inefficiencies. In this section, the respondents were asked to indicate the degree of their agreement or disagreement with the statement given in (Appendix B) for item 12, as illustrated in Table 1.9 below. The variables have been set in Likert scale of 1- 3 as illustrated in table 1.9 below.

Table 1.9: Bandwidth Management Strategies

Variables	Quality of Service (QoS)		Caching & Prefetching		Compression		Load Balancing		Distributed Content	
	F	(%)	F	(%)	f	(%)	f	(%)	f	(%)
1 *(Disagreement)*	41	23.2%	24	13.6 %	29	16.4%	25	14.1%	37	20.9%
2 *(Neutral)*	46	26.0%	39	22.0%	63	35.6%	31	17.5%	78	44.1%
3 *(Agreement)*	90	50.8%	114	64.4%	85	48.0%	121	68.4%	62	35.0%
Total	177	100.0%	177	100.0%	177	100.0%	177	100.0%	177	100.0%

Quality of Service

Quality of Service is *"the collective effect of service performance, which determines the degree of satisfaction of a user of the service"* (Sutinen, 2005, pp. 1-15) allowing preferential treatment to specific applications and network traffic prioritization. In this section, the respondents were asked to indicate the degree of their agreement or disagreement with Quality of Service as used in bandwidth management. From the table 1.9, it is observed that 41 respondents (23.2%) were in disagreement that quality of service enhances service performance. This observed value indicates degree of dissatisfaction among the users in relation to Quality of Service. 46 respondents (26.0 %) were in neutrality about quality of service in regards to service performance. This is attributed to lack of user awareness in existence of bandwidth management policies. 90 respondents (50.8%) were in total agreement that quality of service improves service performance. The results from table 1.9 show that half of the respondents are satisfied with quality of service towards improvement of users experience, service performance and efficient use of network resources.

Prefetching and Caching

In this section, respondents were asked to indicate the degree of their agreement or disagreement with prefetching and caching strategies as used in bandwidth management. From the table 1.9, out of 177 respondents, 24 respondents (13.6%) were in disagreement that caching and prefetching technique enhances WAN performance. This observed value is attributed to respondents trying to search for new information through web pages with cache misses resulting to null web object prefetches. The statistical table 1.9 shows that 39 respondents (22.0%) reported neutral opinion about caching and prefetching technique. 114 respondents (64.4%) were in total agreement that Caching and prefetching technique plays significant role in bandwidth management and optimization. Therefore, it illustrates that caching and prefetching method reduces latency, network traffic control, reduces bandwidth usage, and improves user's satisfaction as well as acceleration of wide area network traffic.

Compression

In this section, respondents were asked to indicate the level of their agreement or disagreement with compression strategy as used in bandwidth management. From the table 1.9, out of 177 respondents, 29 respondents (16.4%) were in disagreement that compression technique optimizes bandwidth and reduces communication costs. The statistical table 1.9 shows that 63 respondents (35.6%) reported neutral opinion about compression technique. This observed value is attributed to lack of user awareness among the respondents. 85 respondents (48.0%) were in total agreement that compression technique ensures utilization of network resources. Tabulated results in table 1.9, shows

that compression method plays critical role in bandwidth management by eliminating duplicate files across the wide area network hence reducing the amount of data transmitted over a channel. This increases capacity of the communication channel allowing maximum link utilization.

Load Balancing

Load balancing is an important technique in bandwidth management. Load balancing permits distribution of network resources with objective of maximizing bandwidth throughput and faster response time. In this section, respondents were asked to indicate the degree of their agreement or disagreement with load balancing as used in bandwidth management. From the table 1.9, 25 respondents (14.1%) were in disagreement that load balancing optimizes bandwidth. The statistical table 1.9 further shows 31 respondents (17.5%) reported neutral opinion about load balancing technique. 121 respondents (68.4%) were in total agreement that load balancing ensures distribution of network resources thus reduce network traffic loads. This indicates that over 50.0% of the respondents were in agreement that load balancing strategy is the best solution to distribute network traffic efficiently and improve network performance thus reducing traffic bottlenecks across the network.

Content Distribution

Content distribution technique allows distribution of resources across the network to enhance content availability, reliability, reduce network latencies and bandwidth utilization. In this section, respondents were asked to indicate the degree of their agreement or disagreement with content distribution method as used in bandwidth

management. From the table 1.9, 37 respondents (20.9%) were in disagreement that content distribution enhances content availability and offers bandwidth optimization. Table 1.9 shows that 78 respondents (44.1%) were in neutrality about content distribution. 62 respondents (35.0%) were in total agreement that content distribution allows distribution of network resources enhancing content availability, reliability, reduce network latencies thus enhance utilization of the available bandwidth effectively. Figure 1.7 below summarizes the results of table 1.9

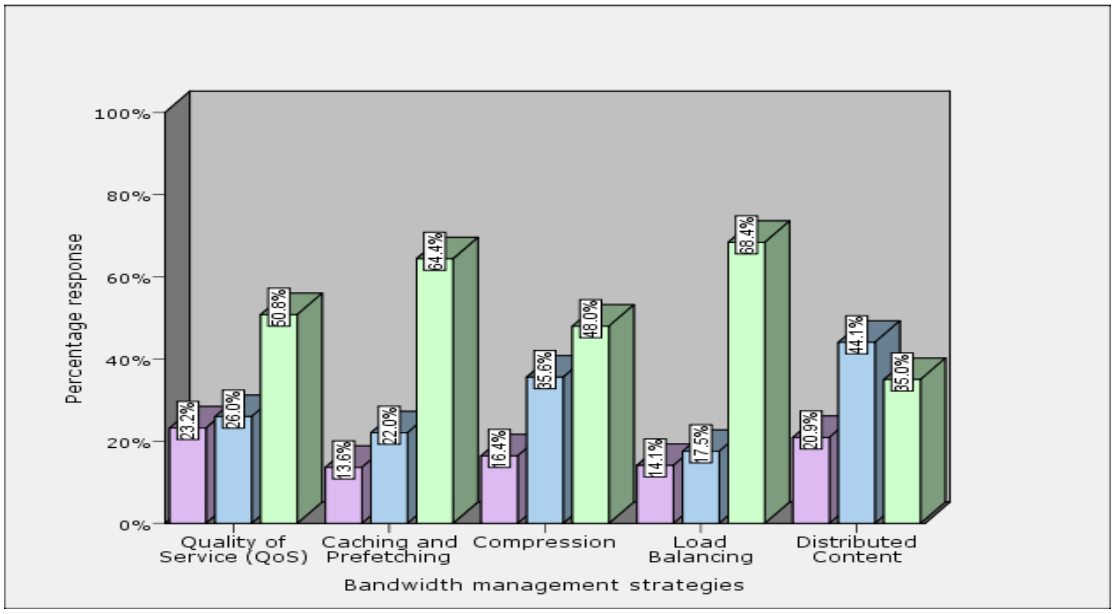


Figure 1.7: Bandwidth Management Strategies

Legend

Disagreement Neutral Agreement

4.5.4 Internet Content Filtering

The internet has contributed to unprecedented network connections and its open nature necessitates controlling the kind of information being accessed. With increased usage of internet and online activity, there is need to conserve network resources and protect

clients against risks such as legal liability. Content filtering allows optimization of available network resources that eases management of network traffic. In this section, the respondents were to indicate the level of their agreement or disagreement with the statement given in (Appendix B) for item 13, as illustrated in Table 1.10 below. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.10.

Table 1.10: Internet Content Filtering

Variables	User Satisfaction		Out of Order Delivery		Internet Monitoring		Information Restriction		Content Availability	
	f	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*	F	*(%)*
1 *(Disagreement)*	108	61.0%	56	31.6 %	35	19.8%	41	23.2%	61	34.5%
2 *(Neutral)*	2	1.1%	80	45.2%	10	5.6%	7	4.0%	22	12.4%
3 *(Agreement)*	67	37.9%	41	23.2%	132	74.6%	129	72.8%	94	53.1%
Total	177	100.0%	177	100.0%	177	100.0%	177	100.0%	177	100.0%

User Satisfaction

In this section, the respondents were asked to indicate the degree of their agreement or disagreement with impacts of internet content filtering. From the table 1.10, it is observed that 108 respondents (61.0%) were in disagreement that user satisfaction is achieved by filtering internet content. This shows that majority of the respondents believe in unfiltered internet content access and they are dissatisfied with internet content filtering service. Only 2 respondents (1.1 %) reported neutral opinion about user satisfaction. 67 respondents (37.9%) were in total agreement that user satisfaction is accomplished by filtering internet content therefore, improves utilization of network resources and services.

Out of Order Delivery

Out of order delivery refers to where data packets are delivered in different order from the way they were sent. In this section, the respondents were asked to indicate the level of their agreement or disagreement with impacts of internet content filtering. From the table 1.10, 56 respondents (31.6%) were in total disagreement that internet filtering causes out of order delivery of packets. Table 1.10 further shows that 80 respondents (45.2%) were in neutrality about impacts of internet content filtering in regards to out of order delivery. 41 respondents (23.2%) were in total agreement that data packets were delivered out of order. The impact of out of order packets on critical applications is grave because packets re-transmission causes performance regression due packet losses hence affecting negatively on bandwidth optimization and utilization of network resources.

Internet Monitoring

In this section, the respondents were asked to indicate the degree of their agreement or disagreement with impacts of internet content filtering. From the table 1.10, 35 respondents (19.8%) were in total disagreement that filtering internet content amounts to internet monitoring and invasion of users privacy. 10 respondents (5.6 %) reported neutral view about internet monitoring. 132 respondents (74.6%) were in total agreement that filtering internet content indeed is a form of monitoring users online activity. Majority of respondents in this group, believe that internet monitoring negates productivity and view it as form of micro-managing what they access hence impeding on their privacy.

Restriction of Information Flow

In this section, the respondents were asked to indicate the level of their agreement or disagreement with impacts of internet content filtering. From the table 1.10, 41 respondents (23.2%) were in disagreement that restriction of information flow occurs as a result of internet content filtering through information censorship and institutionalized filters or policies. Table 1.10 further shows that 7 respondents (4.0%) reported neutral view about restriction of information flow. 129 respondents (72.8%) were in total agreement that internet content filtering restricts information flow therefore, obstructing their entitlement to right of information and contravenes on their freedom of expression.

Content Availability

In this section, respondents were asked to indicate the level of their agreement or disagreement with impacts of internet content filtering. From the table 1.10, out of 177 respondents, 61 respondents (34.5%) reported total disagreement that internet content filtering enhances content availability. Subsequently, 22 respondents (12.4 %) reported neutral opinion about content availability in regards to impacts of filtering internet content. 94 respondents (53.1%) were in total agreement that internet content filtering boost content availability and eases provisioning and bandwidth management planning. Majority of the respondents concurs that filtering internet content enforces compliance and conserve network resources ensuring content availability and reliability. Figure 1.8 below summarizes the results of table 1.10.

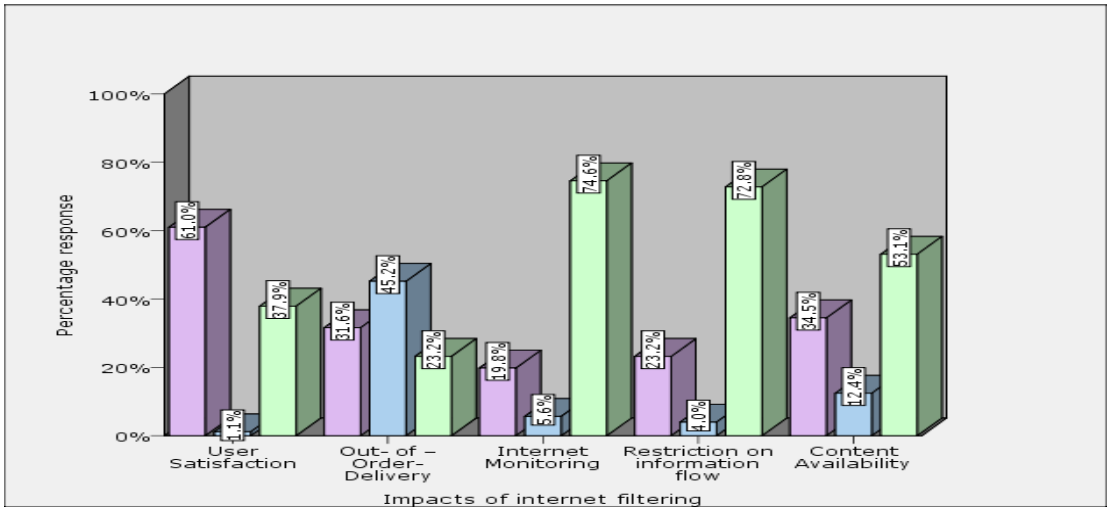


Figure 1.8: Impacts of Internet Filtering

Legend

Disagreement Neutral Agree

4.5.5 Challenges Facing Internet and Intranet Access

The continuous growth of internet traffic has led to prohibitive network traffic loads and unacceptable service response times of internet and intranet access. This is due to increased usage of internet and intranet sites generated by web browsing activities. The wide acceptance of World Wide Web technologies has caused serious challenges of internet and intranet access such as denial of service, slow connections, service disruptions and download delays. In this section, the respondents were asked to indicate the level of their agreement or disagreement with the statement given in (Appendix B) for item 14, as illustrated in Table 1.11 below. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.11.

Table 1.11: Challenges Facing Internet and Intranet Access

Variables	Slow Connection		Service Disruptions		Internet Downtimes		Denial of Service		Download Delays	
	F	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*	F	*(%)*
1 *(Disagreement)*	12	6.7%	10	5.6 %	8	4.5%	31	17.5%	8	4.5%
2 *(Neutral)*	4	2.3%	6	3.4%	4	2.3%	42	23.7%	8	4.5%
3 *(Agreement)*	161	91.0%	161	91.0%	165	93.2%	104	58.8%	161	91.0%
Total	177	100.0%	177	100.0%	177	100.0%	177	100.0%	177	100.0%

Slow Connection

In this section, the respondents were asked to indicate the degree of agreement or disagreement about challenges they face while accessing internet in regards to slow connection. From the table 1.11, out of 177 respondents, 12 respondents (6.7%) were in total disagreement that they experience slow connection when accessing internet and intranet sites. Table 1.10 further shows that only 8 respondents (2.3%) reported neutral view about slow connectivity connection. 161 respondents representing (91.0%) were in total agreement that slow connectivity is one of the challenges they face while accessing internet and intranet sites. This is attributed to unnecessary traffic loads on the network that slows down response time of *http* requests.

Service Disruptions

In this section, the respondents were asked to indicate the degree of agreement or disagreement about challenges they face in accessing internet and intranet sites. From the table 1.11, out of 177 respondents, 10 respondents (5.6%) were in disagreement that

internet service disruptions occurs while accessing internet and intranet sites. The statistical table 1.11 further shows that only 6 respondents (3.4%) reported neutral view about service disruptions. However, respondents rated highly internet service disruptions as one of the biggest challenge they face in internet and intranet access where 161 respondents (91.0%) polled were in total agreement that service disruption is one of the greatest impediments to reliable internet access. This is attributed to many fibre cuts, power outages and frequent network maintenance sanctioned by ISP providers.

Internet Downtimes

Internet downtime refers to periods when internet service is unavailable. In this section, the respondents were asked to indicate the degree of agreement or disagreement about challenges they face in internet and intranet access. From table 1.11, 8 respondents (4.5%) were in disagreement that they experience internet downtimes while accessing internet and intranet sites. The statistical table 1.11 further shows that only 4 respondents (2.3%) in this group reported neutral opinion about internet downtimes. 165 respondents (93.2%) were in agreement that internet downtimes poses the greatest challenge they face when accessing internet resulting to low productivity and revenue losses. This is attributed to many factors such as denial-of service attacks, hardware /software failures, equipment maintenance, fibre cuts, power outages and network congestion among others.

Denial of Service

Denial of service refers to where a user is deprived of service characterized by explicit attempt by hackers to prevent legitimate users of a service from using that service. In this section, the respondents were asked to indicate the degree of agreement or disagreement

about challenges they face in internet and intranet access. From the table 1.11, out of 177 respondents, 31 respondents (17.5%) were in disagreement that they experience denial of service when accessing internet. Subsequently, 42 respondents (23.7%) were neutrality about denial of service. The statistical table 1.11 further shows that 104 respondents (58.8%) were in agreement that denial of service indeed is a inherent network problem that consume network resources and disrupt internet service . This is attributed to SYN flood requests that send data packets to servers without corresponding Acknowledgement causing communication breakdown.

Download Delays

In this section, the respondents were asked to indicate the degree of agreement or disagreement about challenges they face while accessing internet in regards to download delays. From the table 1.11, 8 respondents (4.5%) were in disagreement that they experience download delays when downloading files. Subsequently, 8 respondents (4.5%) were in neutrality about download delays occurrence. The statistical table 1.11 further shows that 161 respondents (91.0%) polled were in total agreement that download delays is one of the biggest challenge they experience especially when downloading files from internet. This slow download delays is due to network congestions, poor bandwidth management policies and network latencies. Figure 1.9 below summarizes the results of table 1.11 above.

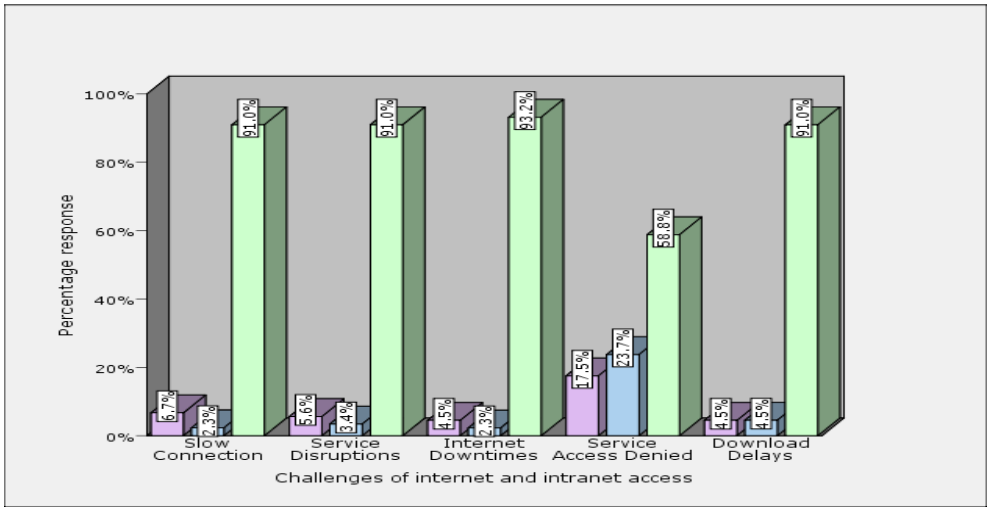


Figure 1.9: Challenges of Internet and Intranet Services

Legend

Disagreement Neutral Agreement

4.5.6 Mode of Internet and Intranet Access

Internet connection mode of access varies according to user's preferences depending on how fast they can connect to the internet. With enormous growth in technology and continuous demand of faster connections, users tend to switch from one mode of access to another based on availability of internet connection. Table 1.12 below, indicates the degree of agreement or disagreement with the statement given in (Appendix B) for item 15, as illustrated in Table 1.12 below. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.12.

Table 1.12: Mode of Internet and Intranet Access

Variables	Local Area Network (LAN)		Wireless Connection		Dial-up Connection		Mobile Broadband Connection	
	F	*(%)*	F	*(%)*	*f*	*(%)*	F	*(%)*
1 *(Disagreement)*	6	3.4%	5	2.8 %	43	24.3%	27	17.5%
2 *(Neutral)*	6	3.4%	5	2.8%	70	39.5%	54	23.7%
3 *(Agreement)*	165	93.2%	167	94.4%	64	36.2%	96	58.8%
Total	177	100.0%	177	100.0%	177	100.0%	177	100.0%

Local Area Network

In this section, the respondents were asked to indicate the degree of agreement or disagreement on mode of access they use while accessing internet. From the table 1.12, out of 177 respondents, only 6 respondents (3.4%) were in disagreement with the statement that they use Local Area Network as mode of accessing internet. 6 respondents (3.4%) reported neutral view about local area network mode of internet access. Moreover, Local Area Network rated highly as the most preferred mode of accessing internet with 165 respondents (93.2%) polled in agreement. Majority of the respondents in this group prefer Local Area Network as mode of accessing internet due its high reliability and higher rates of data transmission without intermittent network failures.

Wireless (Wi-Fi)

In this section, the respondents were asked to indicate the degree of agreement or disagreement on mode of access they use while accessing internet. From the table 1.12, out of 177 respondents, only 5 respondents (2.8%) were in disagreement with the

statement that they use wireless connection as mode of accessing internet. This is can be attributed to intermittent failures that exist within wireless connections and reliability issues. 5 respondents (2.8%) reported neutral view about wireless mode of internet access. 167 respondents (94.4%) were in agreement with the statement that they use wireless connectivity. Most of the respondents in this group favoured wireless connectivity mode of accessing internet due its mobility, scalability and convenience.

Dial-up Connection

Dial-up mode of internet access uses modems or mobile phones to connect to public switched telephone network. In this section, the respondents were asked to indicate the degree of agreement or disagreement on mode of access they use while accessing internet. From the table 1.12, 43 respondents (24.3%) were in disagreement with the statement that they use dial up connectivity as mode of accessing internet and intranet services. This is attributed to its slow connectivity and prone to frequent disconnections experienced in Dial-up connection. The statistical table 1.12 further shows that 70 respondents (39.5%) were in neutrality about use of dial-up connection mode of access. 64 respondents (36.2%) were in agreement with the statement that they use dial up connection since it is inexpensive and convenient to purchase, configure and maintain.

Mobile Broadband Connection

Mobile broadband connection refers to wireless Internet access delivered through mobile phones. In this section, the respondents were asked to indicate the degree of agreement or disagreement on mode of access they use while accessing internet. From the table 1.12, 27 respondents (15.3%) were in disagreement with the statement that they use mobile

broadband connection as mode of accessing internet and intranet services. 54 respondents (30.5%) reported neutral view about mobile broadband connection use in accessing internet and intranet services. 96 respondents (54.2%) were in agreement with the statement that they use mobile broadband connection since it saves time, cost and convenient to use while accessing information. Figure 1.10 below summarizes the results of table 1.12 above.

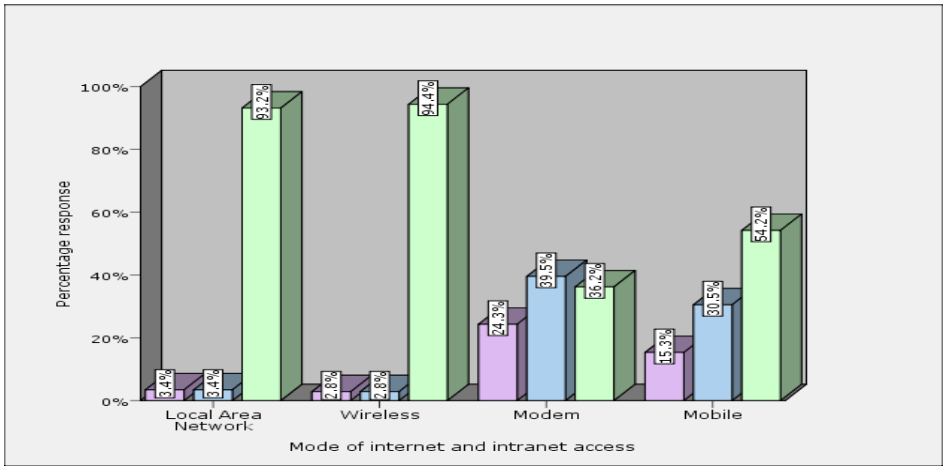


Figure 1.10: Mode of Internet and Intranet Access

Legend

Disagreement Neutral Agreement

4.5.7 Respondents Knowledge on Network Utilization Strategies

Question given in (Appendix B) for item 16 sought to establish whether the respondents know any of the strategies used for network utilization. Table 1.13 below, shows the frequency and percentages on how the sampled participants responded on whether they have knowledge on any strategies used in network utilization.

Table 1.13: Knowledge on Network Utilization Strategies

Variables	Knowledge on network utilization strategies	
	Frequency (*f*)	*Percent (%)*
YES	93	52.5%
NO	84	47.5%
	177	100.0%

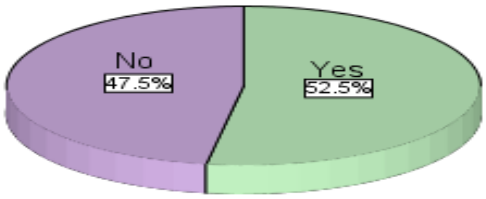


Figure 1.11: Respondents Knowledge on Network Utilization Strategies

4.5.8 Impacts of Bandwidth Management on Web Based Application Access

Bandwidth management is one of the most priority concerns for network administrators today. Bandwidth management is a method for prioritizing network traffic. Bandwidth management network tools allows network administrators to prioritize traffic flow to ensure only critical applications are given more priority on the network than other non-essential services. With increasing bandwidth demands, there is necessity for optimization of network resources to guarantee effective delivery of internet and web based applications to the client. Table 1.14 below, indicates the degree of agreement or disagreement with the statement given in (Appendix B) for item 17 in students questionnaire, as illustrated in Table 1.14 below. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.14.

Table 1.14: Impacts of Bandwidth Management

Variables	Content Availability		Latency Reduction		Improves Efficiency		Academic Performance	
	ƒ	*(%)*	F	*(%)*	*ƒ*	*(%)*	F	*(%)*
1 *(Disagreement)*	34	19.2%	11	6.2 %	10	5.6%	105	59.3%
2 *(Neutral)*	18	10.2%	15	8.5%	9	5.1%	29	16.4%
3 *(Agreement)*	125	70.6%	151	85.3%	158	89.3%	43	24.3%
Total	177	100.0%	177	100.0%	177	100.0%	177	100.0%

Content Availability

In this section, the respondents were asked to indicate the degree of agreement or disagreement on impacts of bandwidth management. From the table 1.14, out of 177 respondents, 34 respondents (3.4%) were in disagreement with the statement that bandwidth management enhances content availability. 18 respondents (10.2%) were neutrality about impacts of bandwidth management in regards to content availability. As illustrated in table 1.14 above, it is clear that significant number of 125 respondents (70.6%) were in agreement with the statement that content availability is a direct benefit of bandwidth management.

Latency Reduction

Latency reduction sets the minimum and maximum standards of access to bandwidth according to business needs. This prevents bandwidth competition from unwanted bandwidth intensive applications. Respondents were asked to indicate the degree of agreement or disagreement on impacts of bandwidth management. From the table 1.14,

11 respondents (6.2%) were in disagreement that bandwidth management reduces network latencies experienced in internet. Table 1.14 further shows that 15 respondents (8.5%) were in neutrality about latency reduction method as used in bandwidth management. Table 1.14 above, shows that a significant number of 151 respondents (85.3%) were in agreement with the statement that latency reduction provides priority service allowing sensitive data to be given preferential treatment over other network traffic.

Improves Efficiency

Bandwidth efficiency is a key metric that measures what portion of bandwidth is utilized effectively to increase productivity and improve network performance. In this section, the respondents were asked to indicate the degree of agreement or disagreement on impacts of bandwidth management. From the table 1.14, out of 177 respondents, 10 respondents (5.6%) were in disagreement with the statement that bandwidth management improves network efficiency. 9 respondents (5.1%) were in neutrality about impacts bandwidth management. Table 1.14 above, shows that a significant number of 158 respondents (89.3%) were in agreement with the statement that bandwidth management indeed improves business efficiency and competitiveness reducing the cost of infrastructure and bandwidth upgrades. Bandwidth efficiency accelerates response time of *http* requests and resolve quality of service problems.

Academic Performance

Proactive bandwidth management is one of the essential methods used to utilize the available bandwidth in order to support and deliver key services without intermittent

network failures. In this section, the respondents were asked to indicate the degree of agreement or disagreement on impacts of bandwidth management. It is clear from table 1.14 above that quite a considerable number of 105 respondents (59.3%) were in disagreement with the statement that bandwidth management improves academic performance. 29 respondents (16.4%) reported neutral view about impacts bandwidth management in reference to academic performance. Table 1.14 above further shows that a less number of 43 respondents (24.3%) were in agreement with the statement that bandwidth management improves academic performance by allowing information delivery in timely manner hence enhanced research in the academic community. Figure 1.12 below summarizes the results of table 1.14.

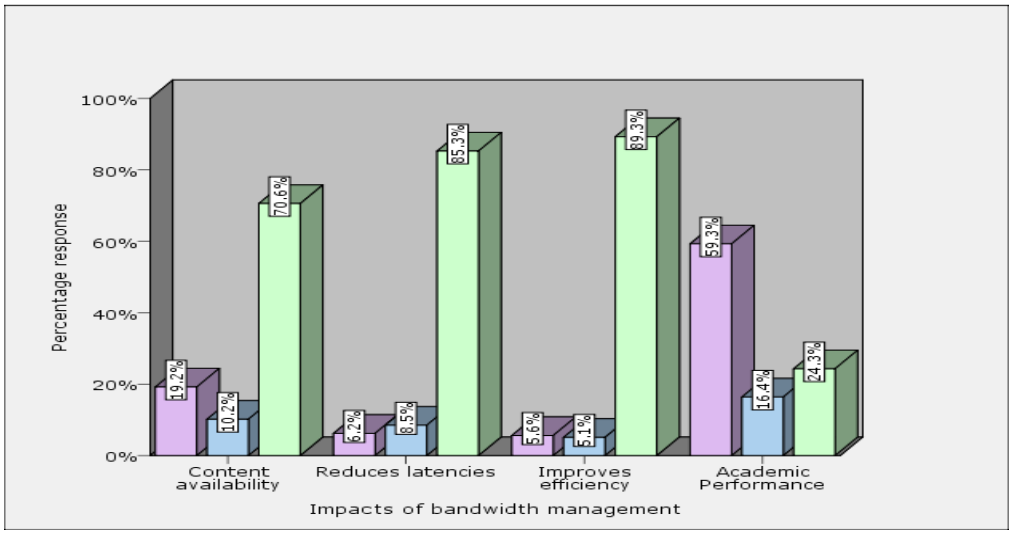


Figure 1.12: Impacts of Bandwidth Management Summary Results

Legend

Disagreement Neutral Agreement

4.5.9 Impacts of Bandwidth Management on Network Security

With increased network security threats, managing network is a paramount activity for network administrators to perform to keep at bay security threats. Secured network assists in leveraging the available bandwidth ensuring optimization of network resources. Secured network enhances network transparency; reduce network traffic and keeps check of unwanted network traffic experienced on the network. Table 1.15 below, indicates the degree of agreement or disagreement with the statement given in (Appendix B) for item 18 in students questionnaire, as illustrated in Table 1.15 below. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.15.

Table 1.15: Impacts of Bandwidth Management on Network Security

Variables	Network Trustworthy		Network Transparency		Reduced Network Traffic	
	f	*(%)*	F	*(%)*	F	*(%)*
1 *(Disagreement)*	38	21.5%	49	27.7 %	17	9.6%
2 *(Neutral)*	60	33.9%	55	31.1%	9	5.1%
3 *(Agreement)*	79	44.6%	73	41.2%	151	85.3%
Total	177	100.0%	177	100.0%	177	100.0%

Network Trustworthy

Network trustworthiness is a concept that entails privacy, security, confidentiality and safety of network resources. In this section, the respondents were asked to indicate the level of agreement or disagreement on impacts of bandwidth management on network trustworthiness. From table 1.15, out of 177 respondents, 38 respondents (21.5%) were in disagreement with the statement that bandwidth management provides improved network

trustworthiness. 60 respondents (33.9%) reported neutral opinion about impacts bandwidth management on network trustworthiness. Table 1.15 above, shows that a considerable number of 79 respondents (44.6%) were in agreement with the statement that bandwidth management enhances network trustworthiness through Demilitarized zones and content filtering.

Network Transparency

Network transparency (Neutrality) is a process of transmitting data over the network in an open manner i.e. free from online non-discrimination and censorship. Network transparency (neutrality) operates from the principle of open platform which is free from impedance from regulatory agencies. In this section, the respondents were to indicate the degree of agreement or disagreement on impacts of bandwidth management on network transparency. From the table 1.15, 49 respondents (27.7%) were in disagreement with the statement that bandwidth management enhances network transparency. 55 respondents (31.1%) reported neutral opinion about impacts of bandwidth management on network transparency. Table 1.15 above, further shows that a considerable number of 73 respondents (41.2%) were in agreement with the statement that bandwidth management facilitates efficient delivery of network services in more transparent manner.

Reduced Network Traffic

In this section, the respondents were asked to indicate the level of agreement or disagreement whether bandwidth management reduces network traffic. From the table 1.15, out of 177 respondents, 17 respondents (9.6%) were in disagreement with the statement that bandwidth management reduces network traffic. Only 9 respondents

(5.1%) reported neutral opinion about reduced network traffic in regards to bandwidth management. Table 1.15 above, shows that a significant number of 151 respondents (44.6%) were in agreement with the statement that bandwidth management indeed reduces network traffic. Figure 1.13 below summarizes the results of table 1.15.

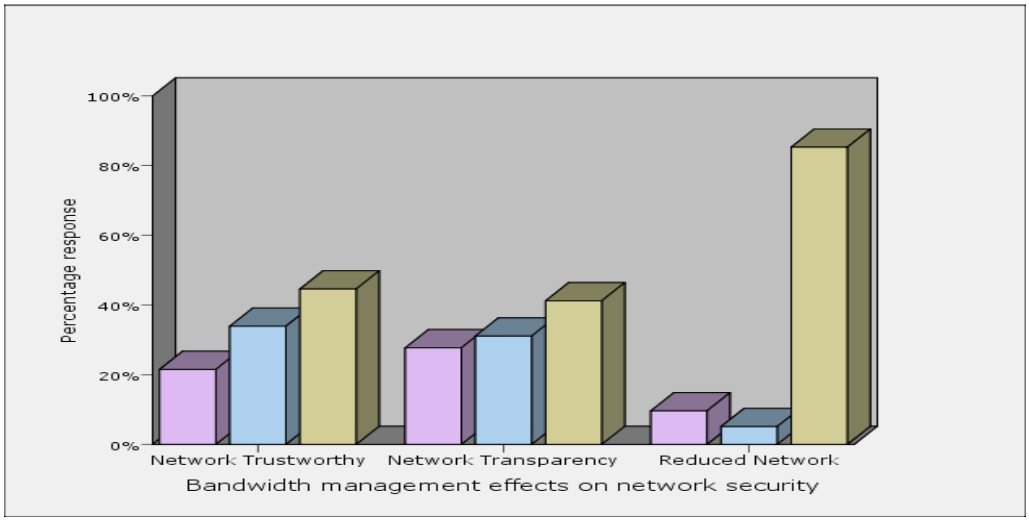


Figure 1.13: Impacts of Bandwidth Management on Network Security Summary

Legend

Disagreement Neutral Agreement

4.6 Staff Sample

This section describes the analyses and discusses of the research findings from the staff questionnaire (see Appendix C) of this study as described in section 3.5.3 of the research design. The research findings in this section relate to the research questions that guided the study.

4.6.1 Staff Categories

The questionnaire was administered to three categories of staff respondents; teaching, IT and management staff. Data were obtained from the staff administered questionnaire, completed by 15 staff respondents (n=15), a 100% response rate. This demonstrates that all the 15 respondents responded to the staff questionnaire and met the required inclusion criteria. This represented 100% of the expected feedback from the staff population. Out of the 15 staff respondents, 11 teaching staff respondents completed the staff questionnaire (73.0%), 2 IT staff respondents completed the staff questionnaire (13.0%) and 2 management staff respondents completed the staff questionnaire (13.0%). Table 1.16 below, shows the frequency and response rate of the respondents sampled in the respective categories.

Table 1.16: Staff Categories

Staff	Staff Categories	
	Frequency (*f*)	*Percent (%)*
Teaching	11	73%
IT	2	13%
Management	2	13%
	15	100.0%

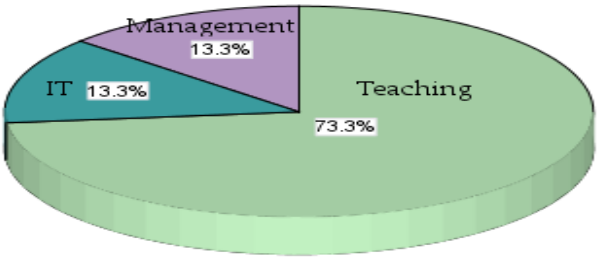


Figure 1.14: Staff Categories Summary Results

4.7 Network Utilization and Performance

4.7.1 Network Utilization and Performance Strategies

Network utilization is the percentage of traffic on a network at any given time. When network utilization is very high, users start to experience latencies in the network resulting slow response times and performance degradations. It is therefore, prudent for system administrations to keep network utilization in constant check in order achieve better network performace. Network utilization and performace can be attained by having good network infrastructure design, proactive network management and bandwidth management policies to keep check on unneccessary network traffic. Table 1.17 below, indicates the level of agreement or disagreement with the statement given in (Appendix C) for item 5 in staff questionnaire. Table 1.17 below, shows the frequency and percentages on how the sampled respondents agree or disagree with network utilization and performance strategies. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.17.

Table 1.17: Network Utilization and Performance Strategies

Variables	Caching		Prefetching		Compression		Traffic Management		Proxy Substitution		Traffic Distribution		Content Filter Service (CFS)	
	f	*(%)*	F	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	(%)	*f*	*(%)*
1 Disagreement	1	6.7%	0	0.0%	1	6.7%	2	13.3%	4	26.7%	2	13.3%	1	6.7%
2 Neutral	1	6.7%	3	20.0%	3	20.0%	1	6.7%	8	53.3%	3	20.0%	2	13.3%
3 Agreement	13	86.6%	12	80.0%	11	73.3%	12	80.0%	3	20.0%	10	66.7%	12	80.0%
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%

Caching

Caching is a process of avoiding a roundtrip to the origin web server each time a resource is requested by a user. In this section, the respondents were asked to indicate the level of agreement or disagreement whether caching is a network utilization and performance strategy. From the table 1.17, out of 15 respondents, only 1 respondent (6.7%) were in disagreement with the statement that caching technique ensures better network utilization and performance. Only 1 respondent (6.7%) reported neutral view about caching technique. Table 1.17 above, shows that 13 respondents (86.6%) were in agreement with the statement that caching technique plays a valuable role in improving utilization of network resources, bandwidth optimization and performance. Caching ensures content is delivered to users in accelerated rate hence improved Quality of Service. A reasonable explanation for the high response rate among the respondents who were in agreement is attributed to the level of user awareness about caching strategy as used in network utilization and performance.

Prefetching

Prefetching technique allows web resources to be brought back closer to the user. In this section, the respondents were asked to indicate the level of agreement or disagreement whether prefetching technique is a network utilization and performance strategy. From the table 1.17, out of 15 respondents, no respondent disagreed with the statement that prefetching technique enhances network utilization and performance. Only 3 respondents (20.0%) were in neutrality about prefetching technique. Table 1.17 above, shows that 12 respondents (80.0%) were in agreement with the statement that prefetching method plays a critical role in improving utilization of network resources by hiding network latencies and reducing network traffic. A probable explanation for the high response rate among the respondents who were in agreement is attributed to the benefits of prefetching in network utilization and bandwidth optimization.

Compression

Compression is a technique used in networking to compress data. Compression technique constricts every bit of bandwidth on a data transmission channel by reducing the size of data frames to be transmitted across the network. In this section, the respondents were asked to indicate the degree of agreement or disagreement on whether compression technique is a network utilization and performance strategy. From the table 1.17, only 1 respondent (6.7%) were in disagreement that compression technique optimizes network resources. 3 respondents (20.0%) were in neutrality about compression strategy as used in network utilization. Table 1.17 above, shows that a significant number of 11 respondents (73.3%) were in agreement with the statement that compression strategy reduces network load usage and optimizes bandwidth.

Network Traffic Management

Network traffic management involves managing and prioritizing network traffic to meet specified bandwidth limits. In this section, the respondents were asked to indicate the level of agreement or disagreement whether network traffic management improves network utilization and performance. From table 1.17, out of 15 respondents, only 2 respondents (13.3%) were in disagreement with the statement that network traffic management provides efficient strategy in controlling and optimizing network resources. Only 1 respondent (6.7%) reported neutral view about network traffic management. Table 1.17 above, shows that 12 respondents (80.0%) were in agreement with the statement that network traffic management plays a critical role in controlling inbound and outbound network traffic therefore; improve resource utilization and quality of service. A reasonable explanation for the high response rate among the respondents who were in agreement is attributed to level of user awareness about existence of network traffic management strategies.

Proxy Substitution

Proxy substitution is a mechanism of redirecting user's requests through proxy servers to request a service. It allows users to make indirect *http* requests to other network services. In this section, the respondents were asked to indicate the degree of agreement or disagreement on whether proxy substitution is a network utilization and performance technique. From the table 1.17, 4 respondents (26.7%) were in disagreement with the statement that proxy substitution optimizes network resources. 8 respondents (53.3%) were in neutrality about impacts of proxy substitution in network utilization. From table 1.17 above, only 3 respondents (20.0%) were in agreement with the statement that proxy

substitution strategy offers network performance through utilization of caches and compression tools. In this section, most of the respondents expressed diverse opinions about proxy substitution method. A reasonable explanation for this is attributed to lack awareness and knowledge about proxy substitution technique among the respondents.

Traffic Distribution

Network traffic distribution is a vital method used in network utilization towards achieving robust and reliable networks. Network traffic distribution involves pre-routing network traffic from servers experiencing congestion to less congested servers in an effort to maximize capacity and minimize network latencies. In this section, the respondents were asked to indicate the degree of agreement or disagreement on whether network traffic distribution enhances network performance and utilization. From the table 1.17, 2 respondents (13.3%) were in disagreement with the statement that network traffic distribution improves network performance and utilization. 3 respondents (20.0%) reported neutral view about immediate benefits of network traffic distribution. From table 1.17 above, 10 respondents (66.7%) were in agreement with the statement that network traffic distribution ensures network resources are not over utilized. Network traffic distribution provides redundancy that cushions the network incase of failsafe in event that one of the network devices becomes unavailable.

Content Filter Servce

Content Filter Service is another important strategy used in prioritizing of network traffic in enforcing protection, business policies and improving productivity by filtering unnecessary traffic content over the network therefore, enhancing network utilization and

performance. In this section, the respondents were asked to indicate the degree of agreement or disagreement on whether content filter service enhances network performance and bandwidth utilization. From the table 1.17, only 1 respondent (6.7%) were in disagreement with the statement that content filter service reduces bandwidth usage. 2 respondents (13.3%) reported neutral about impacts of content filter service. From table 1.17 above, 12 respondents (66.7%) were in agreement with the statement that content filter service plays a critical role in controlling bandwidth usage and improving user's productivity. Content filter service reduces bandwidth cost and accelerates network performance enabling faster response time of *http* traffic and applications. Figure 1.15 below summarizes the results of table 1.17.

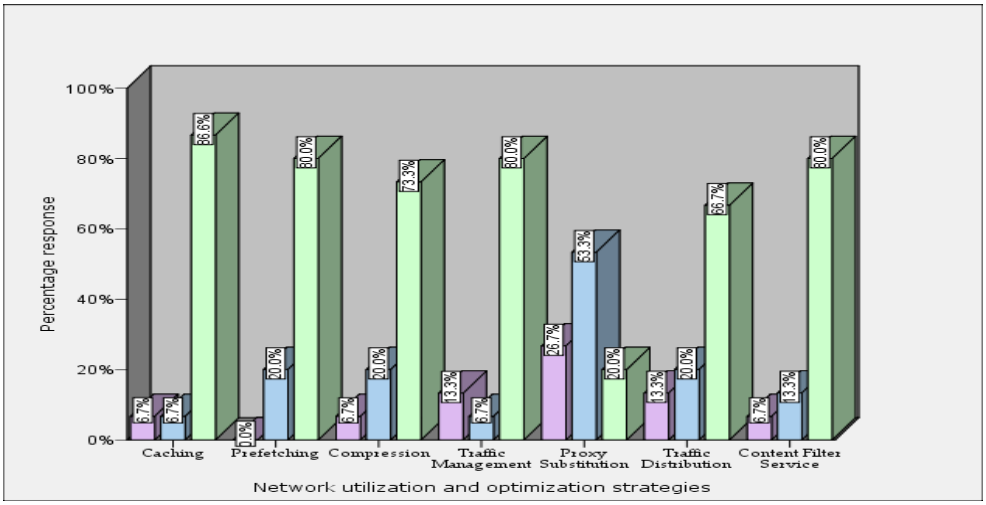


Figure 1.15: Network Utilization and Performance Summary Results

Legend

Disagreement Neutral Agreement

4.7.2 Best practices for Improving Content in Web Applications

The growing demand for faster and uninterrupted access of dynamic web applications necessitates for optimization of web servers and utilization of network tools for efficient delivery of web applications without any form of delay. Table 1.18 below, indicates the degree of agreement or disagreement with the statement given in (Appendix C) for item 6 in staff questionnaire. Table 1.18 below, shows the frequency and percentages on how the sampled respondents agree or disagree with strategies used in improving content in web-based applications. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.18.

Table 1.18: Best Practices for Improving Content Delivery in Web Applications

Variables	Continuous Improvement		Application Development		Content Delivery Networks		Bandwidth Upgrade		Server Upgrades		Infrastructure Upgrade	
	f	*(%)*	*f*	*(%)*	F	*(%)*	*f*	*(%)*	*f*	*(%)*	F	*(%)*
1 *Disagreement*	0	0.0%	0	0.0%	6	40.0%	1	6.7%	1	6.7%	0	0.0%
2 *Neutral*	1	6.7%	0	0.0%	6	40.0%	0	0.0%	1	6.7%	0	0.0%
3 *Agreement*	14	93.3%	15	100.0%	3	20.0%	14	93.3%	13	86.6%	15	100.0 %
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0 %

Continuous Improvement

Continuous improvement is a prerequisite process in keeping web-based applications up to date with cross platform compatibility with current trends in web technologies. In this

section, the respondents were asked to indicate the degree of agreement or disagreement on whether continuous improvement is one of the best practices used in enhancing web performance of web applications. From the table 1.18, none of the respondents disagreed with the statement that continuous improvement is one of the best practices used to enhance web performance of web applications. Only 1 respondent (6.7%) reported neutral view about continuous improvement as a best practice used in improving content in web applications. From table 1.18 above, 14 respondents (93.3%) were in agreement with the statement that continuous improvement plays important role in ensuring content in web applications are up to date thus increasing web performance by accelerating response times for web applications.

Application Development

Developing applications which require less network resources is a guiding principle towards accomplishing network utilization and performance. These less bandwidth applications ensure content in web applications remain reliable and available. In this section, the respondents were asked to indicate the level of agreement or disagreement on whether application development improves content in web applications. The results from the table 1.18 show that none of the respondents disagreed with the statement that application development improves content in web applications. No respondent reported a neutral opinion about application development as one of the best practice used in improving content in web applications. From table 1.18 above, 15 respondents (100.0%) were in agreement with the statement that application development for web applications plays central role in improving content in web applications which impacts positively on network utilization and performance. From the results in Table 1.18, it is evident most of

the respondents in this group expressed a consensus view on application development method as the best practice in improving content in web applications.

Content Delivery Networks

Content delivery network refers to a distributed system of servers that deliver web applications based on geographical proximity of content delivery server (Vakali, 2003, pp. 68-74). Content delivery network enhances the delivery of content of web applications that experience high traffic and have a universal reach. In this section, the respondents were asked to indicate the degree of agreement or disagreement on whether content delivery network is one of the best practices used in accelerating content access in web applications. From the table 1.18, 6 respondents (40.0%) were in disagreement with the statement that content delivery network enhance content in web applications. 6 respondents (40.0%) were in neutrality about impacts of content delivery network. From table 1.18 above, 3 respondents (20.0%) were in agreement with the statement that content delivery network ensures content in web applications is delivered to users with high availability and reliability. Content delivery network helps in preventing network against flood traffic requests. Most of the respondents in this group expressed diverse opinions about content delivery networks method.

Bandwidth Upgrade

Bandwidth upgrades have become a consistent problem for organizations towards meeting bandwidth demands for their users. Organizations have resorted to drastic measures to optimize the available bandwidth rather than upgrading because of economic cost attached to bandwidth upgrades. Therefore, bandwidth upgrades is not a priority or a

viable option due to budget constraints. In this section, the respondents were asked to indicate the level of agreement or disagreement on whether bandwidth upgrade improves content delivery in web applications. From the table 1.18, only 1 respondent (6.7%) disagreed with the statement that bandwidth upgrade is needed to influence content delivery and performance in web applications. No respondent reported a neutral view about bandwidth upgrade as an effective method towards improvement of content delivery in web applications. From table 1.18 above, 14 respondents (93.3%) were in agreement with the statement that bandwidth upgrade is a necessity to realize benefits of accelerated web performance in delivering content of web applications.

Server Upgrades

Server upgrades is a qualification towards realizing network performance and utilization. High end servers with good performance provide the much desired faster response to web applications requests. In this section, the respondents were asked to indicate the level of agreement or disagreement on whether server upgrades enhance content delivery in web applications. The results from the table 1.18 show that 1 respondent (6.7%) disagreed with the statement that server upgrades reinforce content delivery in web applications. Only 1 respondent (6.7%) reported neutral view about server upgrades as a strategy used in improving delivery of content in web applications. 13 respondents (86.6%) were in agreement that server upgrades provides the necessary speed to deploy, manage and process web applications without any constraints.

Infrastructure Upgrade

Network core infrastructure is one of the key solutions to optimize network resources. In

this section, the respondents were asked to indicate the level of agreement or disagreement on whether network infrastructure upgrade optimizes content delivery in web applications. The results from the table 1.18 shows that no respondent disagreed with the statement that network infrastructure upgrade optimize content in web applications. None of the respondents from this group reported a neutral view about infrastructure upgrade as a way of improving content delivery in web applications. All the 15 respondents (100.0%) were in agreement that network infrastructure upgrade is essential in optimizing network security and minimizing downtime thus enhances reliability of content delivery in web applications. From the results in Table 1.18, it is evident that all of the respondents in this group were in agreement that network infrastructure upgrade is a prerequisite towards achieving optimization of content delivery in web applications. Figure 1.16 below summarizes the results of table 1.18.

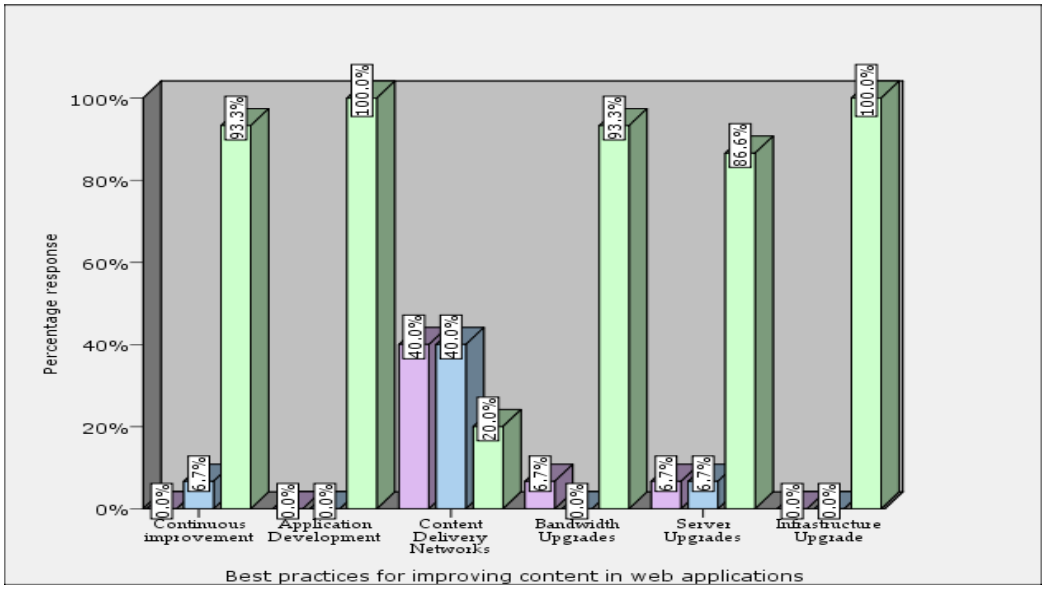


Figure 1.16: Best Practices for Improving Content in Web Applications

Legend

Disagreement Neutral Agreement

4.7.3 Web Applications Use in Streamlining IT Processes and Operations

"Web applications have played important role in streamlining IT processes, operation efficiencies and information delivery in today's corporate, government and educational arenas" (Hacker, 2008). Use of web applications has provided an easy avenue of accessing and sharing information towards streamlining operations within organizations. Table 1.19 below, indicates the degree of agreement or disagreement with the statement given in (Appendix C) for item 7 in staff questionnaire. Table 1.19 below, shows the frequency and percentages on how the sampled respondents agree or disagree with use of web applications in streamlining IT process and operations. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.19.

Table 1.19: Web Applications Usage in Streamlining IT Processes

Variables	Convenience		Maintenance		Reduced Cost		Enhanced Security		Deployment		Cross platform compatibility	
	f	*(%)*	F	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*
1 *(Disagreement)*	1	6.7%	0	0.0%	0	0.0%	6	40.0%	1	6.7%	0	0.0%
2 *(Neutral)*	0	0.0%	1	6.7%	3	20.0%	3	20.0%	3	20.0%	2	13.3%
3 *(Agreement)*	14	93.3%	14	93.3%	12	80.0%	6	40.0%	11	73.3%	13	86.7%
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%

Convenience

Convenience is integral component of web applications. Web applications solutions are easily accessible unlike traditional applications. This enables users to take charge of where and when to access web applications. In this section, the respondents were asked to

indicate the level of agreement or disagreement on convenience of web applications in streamlining IT processes. The results from the table 1.19 show that 1 respondent (6.7%) disagreed with the statement that web applications provide convenient way of accessing and sharing information. No respondent reported a neutral opinion that web applications offer convenience in streamlining IT processes and operations. From table 1.19 above, a significant number of 14 respondents (93.3%) were in agreement with the statement that web applications plays objective role in providing convenience and rationalization of IT costs and operation inefficiencies. From the results in Table 1.19 above, it was evident most of the respondents in this group were in total agreement that use of use web applications provides flexibility and convenience within organizations.

Maintenance

Web applications require less network resources and easy to maintain compared to desktop applications. Since web servers are used, maintenance and troubleshooting issues rarely arises. In this section, the respondents were asked to indicate the level of agreement or disagreement on maintenance of web applications in streamlining IT processes and operations. The results from the table 1.19 shows that no respondent were in disagreement with the statement that web applications are easy maintain. Only 1 respondent (6.7%) reported a neutral view on maintainability of web applications in streamlining IT processes and operations. From table 1.19 above, a significant number of 14 respondents (93.3%) were in agreement with the statement that web applications plays objective role in reducing maintenance and operation inefficiencies. From the results in Table 1.19, it is apparent that most of the respondents were in total agreement that web applications require less network resources therefore, easy maintain compared to desktop applications.

Cost

Web applications are cost-effective since they run on web servers which do not require maintenance fees and utilize small percentage of the disk space therefore, rationalizing IT costs. In this section, the respondents were asked to indicate the degree of agreement or disagreement on cost of web applications in rationalizing IT processes and operations. The results from the table 1.19 show that no respondent was in disagreement with statement that web applications rationalizes costs in IT processes and operations. 3 respondents (20.0%) were in neutrality that web applications rationalizes costs in IT processes and operations. From table 1.19 above, 12 respondents (80.0%) were in agreement with the statement that web applications rationalizes IT costs and processes given that web applications requires minimal support and maintenance.

Enhanced Security

Web applications provide the necessary security by withdrawing the need for a client to access data and back end servers. In this section, the respondents were asked to indicate the degree of agreement or disagreement on security of web applications in streamlining IT processes and process. The results from the table 1.19 show that 6 respondents (40.0%) were in disagreement with the statement that use of web applications provides enhanced security. 3 respondents (20.0%) were in neutrality that use of web applications enhances security. 6 respondents (40.0%) were in agreement with the statement that use of web applications provides enhanced security by removing the need for users to access back end servers. From the results in Table 1.19, it is evident that most of the respondents expressed divergent views on security subject in regards to use of web applications in streamlining IT processes.

Deployment

Web applications do not require any installation since they run on web server hence easier to deploy unlike desktop applications therefore, ideal in places where bandwidth is limited. Web applications allows users to access various services at real time thus streamline IT processes by improving reliability and availability. In this section, the respondents were asked to indicate the level of agreement or disagreement on ease of deployment of web applications in reorganizing IT processes and processes. The results from the table 1.19 shows that only 1 respondent (6.7%) disagreed with the statement that web applications are easy to deploy. 3 respondents (20.0%) were in neutrality that web applications are easy to deploy. 11 respondents (73.3%) were in agreement that web applications are easier to deploy and manage. From the results in Table 1.19, it is evident that most of the respondents expressed diverse opinions on web applications deployment.

Cross Platform Compatibility

Web applications are compatible across different platform and are easier to access than traditional installed software platforms. In this section, the respondents were asked to indicate the degree of agreement or disagreement on cross platform compatibility of web applications in streamlining IT processes and operations. The results from the table 1.19 show that no respondents disagreed with statement that web applications provide cross platform compatibility. 2 respondents (13.3%) were in neutrality that web applications offers cross platform compatibility. 13 respondents (86.7%) were in agreement that web applications are typically across platform since they are accessible from different browsers within various operating systems. Figure 1.17 summarizes the results of table 1.19.

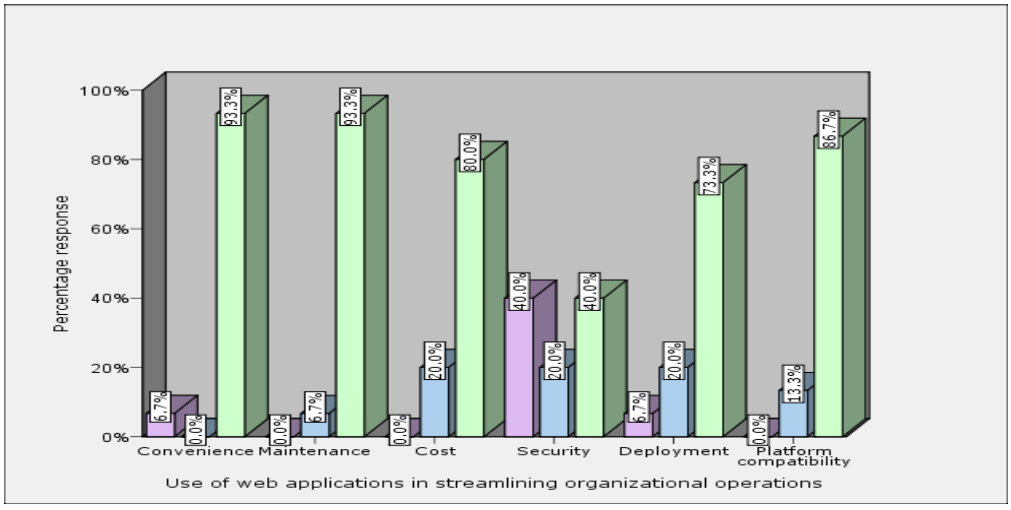


Figure 1.17: Use of Web Applications in Streamlining Organizational Operations

Legend

Disagreement Neutral Agreement

4.7.4 Proxy Server Load Balancing Best Practices

Proxy server load balancing is a method of distributing and pre-routing server's workload across multiple severs across the network to improve *http* response time and enhance service delivery to users. Proxy server load balancing provides queuing and throttling of *http* requests that cause network congestions. Table 1.20 below, indicates the degree of agreement or disagreement with the statement given in (Appendix C) for item 8 in staff questionnaire. Table 1.20 below, shows the frequency and percentages on how the sampled respondents agree or disagree with proxy server load balancing best practices. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.20

Table 1.20: Proxy Server Load Balancing Best Practices

Variables	Reverse Proxy Servers		Network Address Translation		Distributing Network Traffic		Proxy servers firewalls		Content filter Service	
	f	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*
1 *(Disagreement)*	9	60.0%	2	13.3%	1	6.7%	3	20.0%	0	0.0%
2 *(Neutral)*	5	33.3%	7	46.7%	3	20.0%	2	13.3%	1	6.7%
3 *(Agreement)*	1	6.7%	6	40.0%	11	73.3%	10	66.7%	14	93.3%
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%

Reverse Proxy Servers

Reverse proxy is server is an intermediary proxy that sits between the wide area network and local area network. Reverse proxy server can be placed in Demilitarized Zone to allow file transfer services to local area network with less vulnerability attacks from wide area network. It accepts users http requests and forwards the http requests to relevant servers as designated. In this section, the respondents were asked to indicate the level of agreement or disagreement on reverse proxy server load balancing best practice. The results from the table 1.20 show that 9 respondents (60.0%) were in disagreement about reverse proxy server load balancing approach as a way of distributing workload across the network to maximize performance and optimize network resources usage. 5 respondents (33.3%) were in neutrality that reverse proxy server strategy as load balancing best practice. Only 1 respondent (6.7%) was in agreement that reverse proxy server plays critical role in reducing loads at origin servers by caching and compressing content in order to accelerate loading times. Reverse proxy server provides the ability for

availability and scalability through load balancing services. A reasonable explanation for this low response can be seen as lack of user awareness about the use of reverse proxy in distributing load across the network.

Network Address Translation

Network Address Translation is a mechanism that enables modifying of local area network address information to use set of IP addresses for internal traffic as they transit across a traffic routing device for the purpose of remapping one IP address space into another. In this section, the respondents were asked to indicate the level of agreement or disagreement on Network Address Translation proxy server load balancing best practice. The results from the table 1.20 show that 2 respondents (13.3%) were in disagreement that Network Address Translation reduces proxy server loads across the network. This may be attributed to Network Address Translation drawbacks i.e lack of end-to-end traceability and communication delays during IP translation. 7 respondents (46.7%) were in neutrality view about Network Address Translation ability of reducing proxy server loads. 6 respondents (40.0%) were in agreement that Network Address Translation allows load distribution through IP re-addressing therefore, conserve IP address space.

Network Traffic Distribution

Distributing network traffic across the network prevents congestion and other network bottlenecks from occurring. This ensures that network resources are fully optimized. In this section, the respondents were asked to indicate the level of agreement or disagreement on network traffic distribution proxy server load balancing best practice. The data from table 1.20 show that only 1 respondent (6.7%) disagreed that network

traffic distribution reduce *http* workloads experienced across the network. 3 respondents (20.0%) were in neutrality view about network traffic distribution as a best practice of shrinking network traffic loads. 11 respondents (73.3%) were in agreement that network traffic distribution plays crucial role in proxy load balancing by minimizing network traffic loads existing on the network. From the data in Table 1.20, it is evident that respondents expressed mixed opinions about network traffic distribution method.

Proxy Server Firewall

Proxy server firewalls presents the delicate balance between security and functionality. Proxy server firewall provide comprehensive security analysis for the protocols they support hence helps system administrators and network administrators to make better informed security decisions. Proxy server firewall eliminates unnecessary network traffic loads through proxy server filters in order to optimize network usage. In this section, the respondents were asked to indicate the level of agreement or disagreement on proxy server firewall load balancing best practice. The data from the table 1.20 shows that 3 respondents (20.0%) were in disagreement that proxy server firewall filters unwanted network traffic hence reduces traffic workloads. 2 respondents (13.3%) were in neutrality about proxy server firewall capabilities of proxy load balancing. The results from the table 1.20 further indicates that 10 respondents (66.7%) were in agreement that proxy server firewall plays essential role in proxy load balancing by prioritizing and reshaping of network traffic for better utilization of network resources usage. From the data in Table 1.20, it is apparent that respondents expressed diverse opinions about proxy server firewall methodology.

Content Filter Service

Content filter service is a mechanism that is deployed between local area network and wide area network. Content filter service ensures that there is enhanced network security against intrusion; improvement of productivity levels among online users as well optimizing available bandwidth effectively. In this section, the respondents were asked to indicate the level of agreement or disagreement on content filter service load balancing best practice. The data in table 1.20 show that no respondent disagreed with content filter service as a strategy of enhancing load balancing in networks. Only 1 respondent (6.7%) reported neutral view about content filter service as load balancing strategy. 14 respondents (93.3%) were in agreement that content filter service allows traffic prioritization and load balancing in which critical applications are given a priority access. Figure 1.18 summarizes the results of table 1.20.

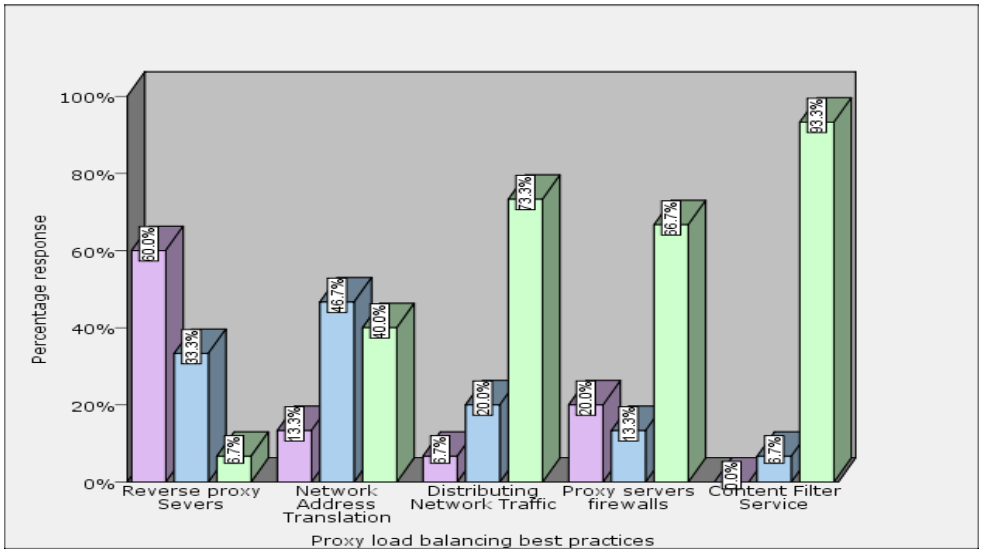


Figure 1.18: Proxy Server Load Balancing Best Practices

Legend

Disagreement Neutral Agreement

4.7.5 Network Traffic Management and Decongestion

Network traffic management and decogestion are some of the solutions needed to resolve network performance degrades caused by cogestion that impede on network resource-sharing. Most network resources have finite capacity that can hold and therefore, it is essential to manage network traffic (Maryland, 2014). Table 1.21 indicates the level of agreement or disagreement with the statement given in (Appendix C) for item 9 in staff questionnaire. The table shows the frequency and percentages on how the sampled respondents agree or disagree with strategies used in network traffic management and decongestion. The variables have been set in Likert scale of 1- 3 as illustrated.

Table 1.21: Network Management and Decongestion

Variables	Fiber Optic Termination		Virtual Private Network		Proxy & Application servers Distribution		Traffic Prioritization & Grooming		Forward Error Correction (FEC)	
	ƒ	*(%)*	*ƒ*	*(%)*	Ƒ	*(%)*	*ƒ*	*(%)*	Ƒ	*(%)*
1 *(Disagreement)*	0	0.0%	0	0.0%	2	13.3%	2	13.3%	1	6.7%
2 *(Neutral)*	0	0.0%	1	6.7%	6	40.0%	4	26.7%	12	80.0%
3 *(Agreement)*	15	100.0%	14	93.3%	7	46.7%	9	60.0%	2	33.3%
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%

Fiber Optic Termination

Fiber optic termination is the ultimate solution to solve data communication problems. Fiber optic increases upstream and downstream bandwidth unlike peer to peer networks which are prone to intermittent network failure, interference and signal degradation. Fiber

optic provides low attenuation thus reduce network traffic congestion experienced across network. In this section, the respondents were asked to indicate the level of agreement or disagreement on fiber optic termination as used in network management and decongestion of network traffic. The data in table 1.21 show that no respondent disagreed with fibre optic termination as a strategy of solving network management and decongestion issues. Moreover, no respondent reported neutral view about fibre optic termination as an approach in network management and decongestion of network traffic. The data from the table 1.21 further shows, that all the 15 respondents (100.0%) were in total agreement that fiber optic termination is the ultimate solution to deal with network latency and congestion issues.

Virtual Private Network

Virtual Private Network is a private network that utilizes a virtual tunnel or trucking to connect remote sites and share data securely. Virtual Private Networks enable organizations to reduce IT costs and optimize productivity compared to Wide Area Network technology. In this section, the respondents were asked to indicate the level of agreement or disagreement on Virtual Private Network as used in network management. The data from the table 1.21 shows that no respondent disagreed with Virtual Private Network methodology as a way optimization of network resources. Only 1 respondent (6.7%) reported neutral the view about Virtual Private Network use in managing network congestion. 14 respondents (93.3%) were in agreement that Virtual Private Networks plays major role in network management and decongestion of network traffic loads.

Proxy and Application Servers Distribution

Distribution of proxy and application servers provides overall better service delivery performance that centralized proxies and servers which are frequently under the threat of heavy network traffic loads. This distribution of servers ensures cost-effective methodology to drive utilization of network resources efficiently. The data from table 1.21 shows that 2 respondents (13.3%) were in disagreement that distribution of proxy and application servers across the network decrease network traffic loads across the network. 6 respondents (40.0%) were in neutrality view about the use of proxy and application servers in managing network congestion. 7 respondents (46.7%) were in agreement that distribution of proxy and application servers provides the much needed performance by reducing loads that culminate to network traffic decongestion. From the data in Table 1.21, it is evident that respondents expressed mixed opinions about proxy and application servers as a strategy of distributing network traffic.

Traffic Prioratization and Grooming

Traffic prioritization and reshaping are some of vital techniques used in reducing network traffic bottlenecks occurring across the network. Traffic grooming and prioritization ensures optimization of network resources by increasing usable bandwidth and reducing network latencies and network congestions experienced over the network. This guarantees Quality of Service and Return on investment through efficient use of available bandwidth. The data from table 1.21 depicts that 2 respondents (13.3%) disagreed that traffic prioritization and grooming minimizes network congestion. 1 respondent (6.7%) reported neutral view about traffic prioritization and grooming as a method used in network management and decongestion. 9 respondents (60.0%) were in agreement that

traffic prioritization and grooming reduces network traffic loads across the network.

Forward Error Correction

Forward error correction is a technology used to detect errors in data transmission and correct without retransmitting the data packets. Forward error correction extends signal quality thus reduce intermittent connection failures and network impairments within long distance ranges (Nee, 2011, pp. 9-20). Forward error correction ensures that any lost packets are recovered to avoid retransmission hence enhances network throughput and reduce network congestion. The results from table 1.21 show that only 1 respondent (6.7%) disagreed that forward error correction reduces *http* traffic consequently, easing network traffic congestion. 12 respondents (80.0%) were in neutrality view about forward error correction as method of reducing network congestion. 2 respondents (13.3%) were in agreement that forward error correction plays important role in network management and decongestion by reducing network traffic loads across the network. From the data in Table 1.21, it is evident there is divergence of opinions among the respondents in regards forward error correction mechanism. Figure 1.19 below summarizes the results of table 1.21.

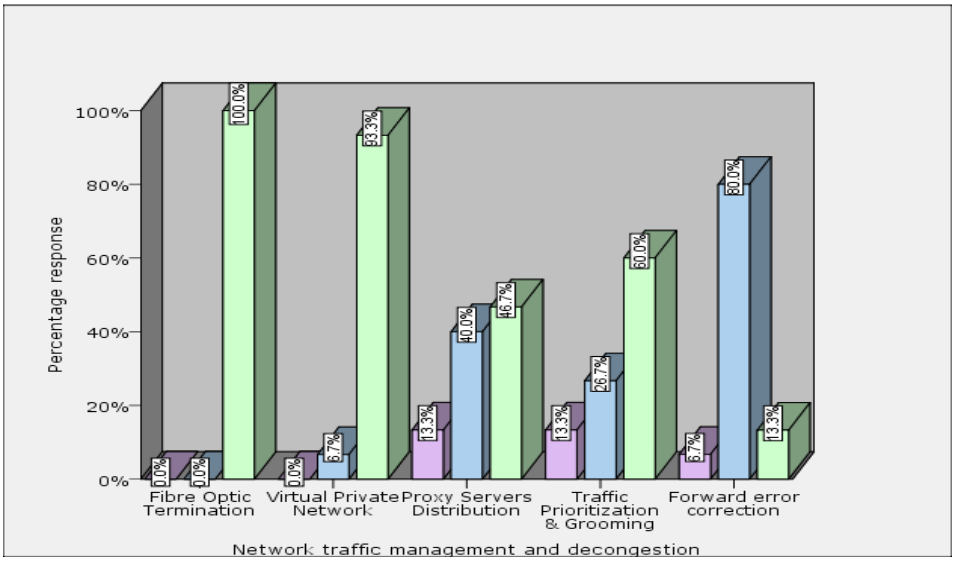


Figure 1.19: Network Management and Decongestion

Legend

Disagreement Neutral Agreement

4.7.6 Query Optimization Strategies

Query optimization is a technique of producing an optimal query execution plan while operating within a set of resource constraints. Query optimization technique enhances performance of declarative queries in objected oriented database systems therefore, ensures effective utilization of network resources and reduce bandwidth demands hence a cost-saving strategy. Table 1.22 indicates the level of agreement or disagreement with the statement given in (Appendix C) for item 10 in staff questionnaire. The table shows the frequency and percentages on how the sampled respondents agree or disagree with query optimization strategies. The variables have been set in Likert scale of 1- 3 as illustrated.

Table 1.22: Query Optimization Strategies

Variables	SQL Query Tuning		Query Indexing		Clustering		Server Tuning		De-normalization		Tables Partitioning	
	f	*(%)*	F	*(%)*	F	*(%)*	*f*	*(%)*	*f*	*(%)*	F	*(%)*
1 *(Disagreement)*	0	0.0%	1	6.7%	0	0.0%	0	0.0%	0	0.0%	2	13.3%
2 *(Neutral)*	2	13.3%	0	0.0%	9	60.0%	5	33.3%	9	60.0%	8	53.4%
3 *(Agreement)*	13	86.7%	14	93.3%	6	40.0%	10	66.7%	6	40.0%	5	33.3%
Total	15	100.0%	15	100.0 %	15	100.0 %	15	100.0 %	15	100.0%	15	100.0%

SQL Query Tuning

Query performance tuning is one of the key mechanisms to ensure that queries in database applications are running within acceptable performance metrics. Query tuning entails finding more effective method in processing optimum query with lowest estimated cost and execution plan within the same workload. Query Performance tuning plays immense role in running of database applications by reducing time required by queries to response and display results. Query performance tuning permits query throttling to mitigate performance issues associated to slow SQL queries in database applications. In this section, the respondents were asked to indicate the degree of agreement or disagreement on SQL Query tuning as a query optimization strategy. The data from the table 1.22 shows that no respondent disagreed with SQL Query tuning as a strategy of enhancing query throughput of database applications towards ensuring efficient optimization of network resources. Only 2 respondents (13.3%) were in neutrality view that SQL Query tuning improves performance through optimization of SQL queries in

database applications. 13 respondents (86.7%) were in agreement that SQL query tuning plays central role by reducing response time of query workloads and increasing query throughput levels. SQL query tuning reduces network traffic and balance query workloads during peak times ensuring optimization and utilization of network resources.

Query Indexing

Query indexing is a process of improving performance of a query through a primary data structure constraint in a table. This can be created using one or more database columns to provide the basis for lookups to access database records with least execution time. Query indexing technique avoids full database table scans by utilizing indexes for fast data retrieval for specific values in a database table column. In this section, the respondents were asked to indicate the degree of agreement or disagreement on Query indexing as a query optimization strategy. The data from the table 1.22 shows that 1 respondent (6.7%) disagreed that Query indexing reduces query execution time and query retrieval of data in database applications. No respondent reported neutral view about Query indexing. 14 respondents (93.3%) were in agreement that query indexing performs query optimization in database applications by speeding up queries and reducing network latencies. Query indexing avoids the necessity of scanning all tables for optimum performance thus optimizing data retrieval process in queries through unique clustered indexes.

Clustering

Clustering refers to grouping of related items stored together for efficiency of access and resource utilization (Versant, 2014). This enables several instances to connect to a single database environment. Clustering technique plays key role in load balancing by

connecting clients to servers having less workloads. Moreover, clustering offers high fault tolerance since they are more than one instance running hence minimal downtime periods. The data from table 1.22 shows that no respondent disagreed with clustering as an approach of providing high availability for database applications and network resource throttling during failovers. 9 respondents (60.0%) were in neutrality about clustering technique as a method of reducing workloads in database applications. 6 respondents (40.0%) were in agreement that clustering technique plays crucial role in database applications in load balancing and fault tolerance therefore, provides effective method of resource utilization and optimization.

Server Tuning

Server tuning is a process of adjusting server system configuration to optimize the level of performance standard requirements of the database applications. Server tuning improves response time required when accessing database applications. The data from table 1.22 shows that no respondent disagreed with server tuning as a strategy in optimizing server performance. 5 responses (33.3%) were in neutrality about server tuning technique as a method of reducing workloads in database applications. Data in table 1.22 further shows that 10 respondents (66.7%) were in agreement that server tuning is authentic way to optimize server performance and improve server's response time when accessing database applications. Consequently, server tuning grants better user experience and utilization of network resources effectively.

Denormalization

Denormalization is the process of optimizing the read performance of relational databases by adding redundant data to cover up the inefficiencies inherent in relational database management systems (Sanders, 2001, p. 1). Denormalization increases performance and scalability of relational databases by minimizing number of joins and tables therefore, denormalization is a time-space trade-off. The data from table 1.22 shows that no respondent disagreed with denormalization method as a way of improving query performance in database applications. 9 respondents (60.0%) were in neutrality about denormalization as a strategy in enhancing query performance in database applications. Data in table 1.22 further shows that 6 respondents (40.0%) were in agreement that denormalization strategy plays a critical role in database applications by reducing ineffectiveness of queries slowing performance in relational databases.

Table Partitioning

Table partitioning in relational database management systems is one of the key components used to decompose large tables and indexes into smaller storage partitions to ease access of database objects. Table partitioning ensures faster response of queries by index defragmentation and partition elimination to improve query performance when accessing database applications. In this section, the respondents were asked to indicate the degree of agreement or disagreement on table partitioning as a query optimization method. The data from table 1.22 shows that 2 responses (13.3%) were in disagreement with table partitioning technique. 8 responses (53.3%) were in neutrality about table partitioning improves query performance in database applications. 5 respondents (33.3%) were in agreement that table partitioning strategy plays a critical role in database

applications by improving query performance during retrieval process and efficient utilization of index defragmentation at table partition levels. Figure 1.20 summarizes the results of table 1.22.

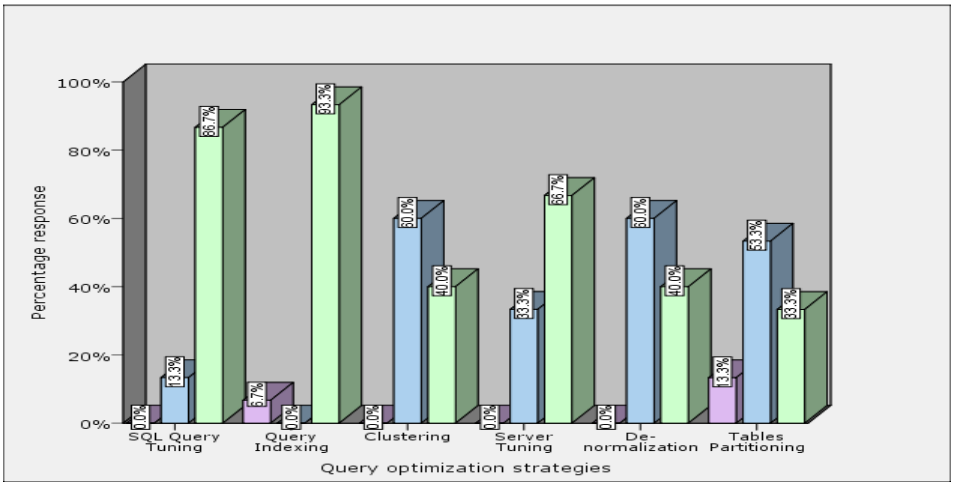


Figure 1.20: Query Optimization Strategies

Legend

Disagreement Neutral Agreement

4.7.7 Improving Query throughput and Load Balancing

Query throughput is a process of determing performance and response time of a transaction query to perform an execution task in a database system. The response time for a transaction query tends to decrease with increase in overall throughput and vice versa therefore query throughput measures the general performance and load balancing of a database system (Harrison, 2000). Table 1.23 indicates the level of agreement or disagreement with the statement given in (Appendix C) for item 11 in staff questionnaire. Table 1.23 below, shows the frequency and percentages on how the sampled respondents agree or disagree with methods used in accomplishing query throughput and query load balancing. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.23.

Table 1.23: Improving Query throughput and Load Balancing

Variables	Query Restructuring		Query Simplification		Query Indexing		Virtual Private Network		High Performance Servers	
	ƒ	*(%)*	F	*(%)*	*ƒ*	*(%)*	*ƒ*	*(%)*	*ƒ*	
1 *(Disagreement)*	2	13.3%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2 *(Neutral)*	3	20.0%	0	0.0%	1	6.7%	1	6.7%	0	0.0%
3 *(Agreement)*	10	66.7%	15	100.0%	14	93.3%	14	93.3%	15	100.0%
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%

Query Restructuring

Query restructuring involves rewriting inefficient query statements to new statements that meet minimum requirements of query efficiency with effective optimal execution plan and cost. Using query restructuring in query optimization results to significant reduction in query processing costs which in turn save valuable bandwidth (Chen D. , 2009, pp. 353-370). Query restructuring helps to reduce redundant query predicates by eliminating unnecessary query joins. In this section, the respondents were asked to indicate the level of agreement or disagreement whether query restructuring improves query throughput and load balancing. The data from table 1.23 shows that 2 responses (13.3%) disagreed with query restructuring method as a mechanism of improving query throughput and query load balancing in database applications. 3 respondents (20.0%) were in neutrality opinion about query restructuring as means of enhancing query throughput and load balancing in database applications. 10 respondents (66.7%) were in agreement that query restructuring ensures optimal execution plan is achieved through reduction in query processing costs which helps to improve query throughput and performance.

Query Simplification

Query simplication is a new paradigm shift for optimizing large complex queries by decomposing queries until optimization problem becomes good within a set of query constraints. Query simplication ensures that query problems are solved optimally by applying simple query rules to achieve the best execution plan in relational databases (Neumann, 2009, pp. 403-414). In this section, the respondents were asked to indicate the level of agreement or disagreement whether query simplification enhances query throughput. The data from table 1.23 shows that no respondent disagreed with Query simplication method. Moreover, no respondent reported a neutral view in regards to Query simplication method. All the 15 respondents (100.0%) were in agreement that Query simplication technique plays a major role in improving query throughput and load balancing in database applications by decomposing complex queries to simpler queries with optimal execution plan and cost.

Query Indexing

Query indexing technique widely in enhancing query processing in relational database management systems. Query indexing improves performance by avoiding full database table scans during data retrieval processes therefore, faster response time for query results. In this section, the respondents were asked to indicate the level of agreement or disagreement whether query indexing enhances query load balancing and throughput .The data from the table 1.23 shows that no respondent disagreed with Query indexing strategy. Only 1 respondent (6.7%) reported a neutral opinion about Query indexing as means of improving query load balancing and throughput in database applications. 14 respondents (93.3%) were in agreement that query indexing is an effective method to improve query throughput and load balancing in database applications.

Virtual Private Network

Virtual Private Network is an extended private network within a local area network or wide area network. Virtual Private Network provides enhanced security in keeping data secured and encrypted. This prevents hackers from creating SYN flood attacks on database applications hindering its performance. Database applications sitting on Virtual Private Network networks have greater capability for better performance and low maintenance cost. This ensures effective utilization of bandwidth, throughput and network resources usage. In this section, the respondents were asked to indicate the degree of agreement or disagreement whether Virtual Private Network improves query load balancing and throughput in database applications. The data from table 1.23 shows that no respondent disagreed with Virtual Private Network usage as a method of enhancing query load balancing in database applications. Only 1 respondent (6.7%) reported a neutral opinion about Virtual Private Network as means of improving query load balancing and throughput in database applications. 14 respondents (93.3%) were in agreement that Virtual Private Network indeed increases query throughput by preventing SYN floods in database applications that hinder performace.

High Performace Servers

High performance servers provide the computing power needed to access database applications more efficiently to meet ever-increasing demand for online resources with high reliability and availability. In this section, the respondents were asked to indicate the degree of agreement or disagreement whether high performance servers optimizes accessibility of database applications. The frequency from table 1.23 shows that no respondent disagreed with high performance servers as a way of improving accessibility

of database applications. Moreover, no respondent reported neutral view in regards to high performance servers. 15 respondents (100.0%) were in agreement that high performance servers plays a major role in improving accessibility in database applications as well as higher throughput levels and load balancing in database applications by utilizing server computing power. Figure 1.21 below summarizes the results of table 1.23 above.

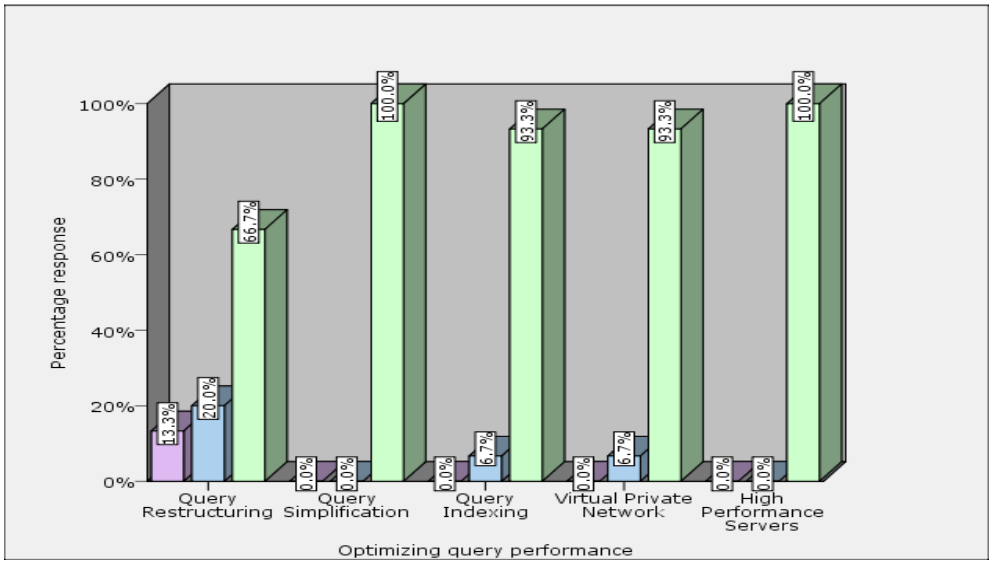


Figure 1.21: Optimizing Query Performance

Legend

Disagreement Neutral Agreement

4.7.8 Latency Management Strategies

Latency management is a process of controlling and minimizing unnecessary network traffic delays that impedes on data transmission in an efficient way by window-size scaling. Latency management plays critical role in controlling propagation delays in network transmission which in turn improve the available bandwidth. Table 1.24 below, indicates the degree of agreement or disagreement with the statement given in (Appendix

C) for item 12 in staff questionnaire. Table 1.24 below, shows the frequency and percentages on how the sampled respondents agree or disagree with methods used in latency management. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.24.

Table 1.24: Latency Management Strategies

Variables	Bandwidth Upgrade		Network Traffic Shaping		Proxy Firewall Rules		Network Address Translation (NAT)	
	ƒ	*(%)*	*ƒ*	*(%)*	F	*(%)*	*ƒ*	*(%)*
1 *(Disagreement)*	1	6.7%	0	0.0%	0	0.0%	2	13.3%
2 *(Neutral)*	0	0.0%	3	20.0%	2	13.3%	8	53.3%
3 *(Agreement)*	14	93.3%	12	80.0%	13	86.7%	5	33.3%
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%

Bandwidth Upgrade

Bandwidth upgrade is process of complementing the existing bandwidth to meet the current bandwidth demands by users. The frequency table 1.24 shows that only 1 respondent (6.7%) disagreed with bandwidth upgrade as method used in managing network latency. No respondent reported neutral view in regards to bandwidth upgrade. 14 respondents (93.3%) were in agreement that bandwidth upgrade is necessary to solve inherent network latency problems and promote faster applications performance.

Network Traffic Shaping

Network traffic shaping is a practice of regulating flow of data packects to guarantee certain level of performance by prioritizing important traffic and delaying less desired

network data traffic (Bechler et al., 2000, pp. 1-6). Network traffic shaping ensures bandwidth available is controlled and managed through network access policies created in regulating flow of traffic to avoid network bottelnecks. This method of bandwidth throttling is performed to guarantee Quality of Service to ensure effective use bandwidth and network resources. The frequency table 1.24 shows that no respondent disagreed that network traffic shaping reduce latencies on the network. 3 respondents (20.0%) were in neutrality about network traffic shaping as means of minimizing network latencies. 12 respondents (80.0%) were in agreement that network traffic shaping reduce network latencies by prioritization of network traffic for critical applications.

Proxy Firewall Rules

Proxy firewall rules plays central role in filtering unnecessary network traffic thus reduce security risks as well as saving bandwidth. Firewall rules cushions the network from external attacks that may cause latencies over the network or denial-of-service to users. The frequency table 1.24 shows that no respondent disagreed that proxy firewall rules reduce latencies on the network. 2 respondents (13.3%) were in neutrality opinion about Proxy firewall rules in managing network latencies. 13 respondents (86.7%) were in agreement that proxy firewall rules indeed helps in managing latency by providing comprehesive filtering rules that eliminates unnecessary network traffic loads.

Network Address Translation

Network Address Translation is a mechanism that enables modifying of local area network address information to use set of IP addresses for internal traffic as they transit across a traffic routing device for the purpose of remapping one IP address space into

another. The results from the table 1.24 show that 2 respondents were in disagreement that Network Address Translation provides effective method in latency management. Moreover, 8 respondents were in neutrality opinion about Network Address Translation in latency managementy. 5 respondents (53.3%) were in agreement that Network Address Translation plays critical role in managing latency in congested networks. Figure 1.22 below summarizes the results of table 1.24.

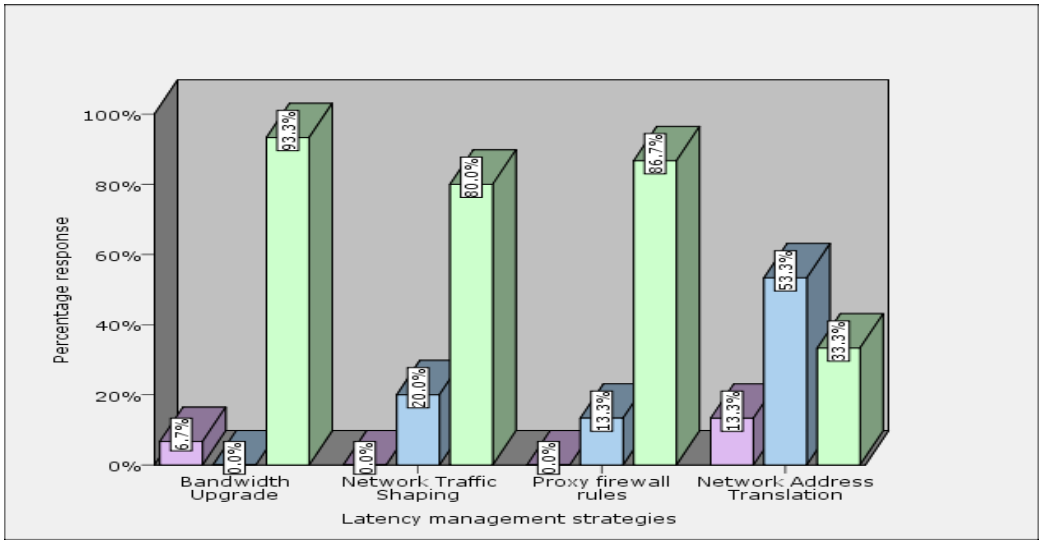


Figure 1.22: Latency Management Strategies

Legend

Disagreement Neutral Agreement

4.7.9 ICT Policy

ICT policy is document that seeks to guide consumers and users of information and ICT resources on appropriate standards that constitute acceptable use of the ICT resources. ICT policy covers a spectrum of issues like security, communication infrastructure, network services, training, procurement and others. ICT policy is a prerequisite document that streamlines internal operations within institutions. ICT policy plays important role of

providing roadmap in addressing digital gaps in institutions. ICT policy helps to identify and maximize use of ICT resources more effectively. Item 13 of the staff questionnaire (Appendix C) tries to establish respondent's awareness about ICT policy. Figure 1.23 below, shows percentages on how the sampled respondents level of awareness about presence of ICT Policy. The pie chart in figure 1.23 shows that (60.0%) of responses were received from the respondents acknowledging existence of ICT policy while remaining (40.0%) of the respondents disagreed the existence of ICT policy. From figure 1.23, it is clear that more that half of the respondents are aware of existence of ICT policy as illustrated in the figure 1.23. The figure 1.23 below summarizes the responses received from the respondents sampled.

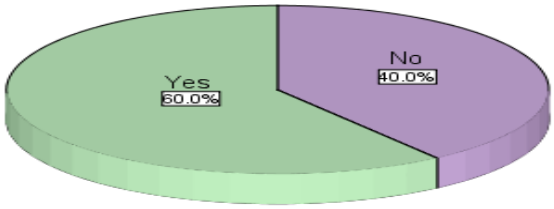


Figure 1.23: Existence of ICT Policy

4.7.10 ICT Policy Based Bandwidth Management

Item 14 of the staff questionnaire (Appendix C) targets respondents who acknowledge existence of ICT policy as stated in section 4.8.9. Respondents were asked whether the current ICT policy supports bandwidth management. Figure 1.25 shows that (77.8%) of responses were received from the respondents concurring that the current ICT policy supports bandwidth management while (22.2%) of the respondents disagreed that the current ICT policy supports bandwidth management. From figure 1.24, it can be adduced that current ICT policy covers optimization of network resources in accordance

bandwidth management policies ensuring better Quality of Service. The pie chart in figure 1.24 below summarizes the responses received from the respondents acknowledging that the current ICT Policy supports network utilization and performance as illustrated.

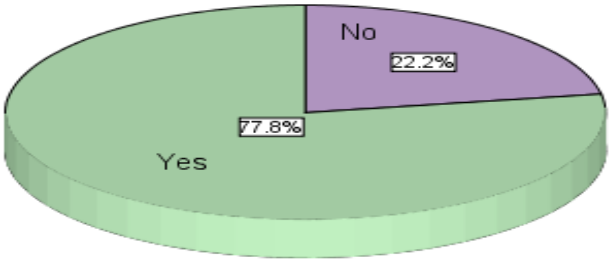


Figure 1.24: ICT Policy Based Bandwidth Management

4.7.11 Effects of Bandwidth Management

Bandwidth management is a method for prioritizing network traffic to allow only critical applications have a higher priority on the network compared to less critical applicantions. Bandwidth management improves Quality of Service by enhancing network response times and accelarate download speeds within the institution. Table 1.25 below, indicates the degree of agreement or disagreement with the statement given in (Appendix C) for item 15 in staff questionnaire. Table 1.25 below, shows the frequency and percentages on how the sampled respondents agree or disagree with effects of bandwidth management. The variables have been set in Likert scale of 1- 3 as illustrated Table 1.25.

Table 1.25: Effects of Bandwidth Management

Variables	User Satisfaction		Network Traffic Acceleration		Optimized Bandwidth		Reduced Bandwidth cost		Reduce Traffic Congestion	
	f	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	*(%)*	*f*	
1 *(Disagreement)*	4	26.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2 *(Neutral)*	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4	26.7%
3 *(Agreement)*	11	73.3%	15	100.0%	15	100.0%	15	100.0%	11	73.3%
Total	15	100.0%	15	100.0%	15	100.0%	15	100.0%	15	100.0%

User Satisfaction

The data from table 1.25 shows that 4 respondents (26.7%) were in disagreement that the bandwidth management grants user satisfaction. No respondent reported neutral view in regards to impacts bandwidth management on user satisfaction. 11 respondents (73.3%) were in agreement that bandwidth management indeed improves user safisfaction and quality of service by prioritizing network traffic from business critical applications ensuring satisfying end-user experience.

Network Traffic Acceleration

Network traffic acceleration plays important role in optimization of network resources. Network traffic acceleration reduces congestion and limit packet losses in TCP connections by eliminating false Acknowledgements by compressing TCP packets thus enhanced performance. No respondent disagreed with network traffic acceleration. No respondent reported neutral view in regards to network traffic acceleration. All the 15 respondents (100.0%) were in total agreement that network traffic acceleration improve throughput and network performance.

Optimized Bandwidth

Bandwidth optimization is a mainstream technology used within institutions in improving network performance and reducing bandwidth demands. The data from table 1.25 shows that no respondent disagreed that optimized bandwidth is as a result of bandwidth management. No respondent reported neutral opinion about optimized bandwidth in regards to bandwidth optimization. All the 15 respondents (100.0%) were in total agreement that bandwidth management indeed optimizes the available bandwidth therefore, enhance Quality of Service (QoS).

Reduced Bandwidth Costs

With current bandwidth optimization technologies, network administrators can monitor network traffic and use the information to allocate bandwidth according to institutional needs. This ensures enhanced network performance by delivering cost-efficient and reliable network. In this section, the respondents were asked to indicate the degree of agreement or disagreement on effects of bandwidth management in regards to bandwidth costs. The data from table 1.25 shows that no respondent disagreed about impacts of bandwidth management in regards to bandwidth cost reduction. No respondent reported neutral view about impacts of bandwidth optimization towards reducing cost. All the 15 respondents (100.0%) were in total agreement that bandwidth management undeniably reduce bandwidth costs. This ensures efficient usage of bandwidth allocated hence no extra connections incurred therefore saving money.

Reduce Traffic Congestion

High network traffic congestion cause bottlenecks on the network which impede on flow of data traffic by slowing or stopping network traffic entirely. This occurs due to sub-optimal configuration and poor practices in bandwidth management methods. The data from the table 1.25 shows that no respondent disagreed that bandwidth management minimizes network congestion. Only 4 respondents (26.7%) were in neutrality about impacts of bandwidth management. 11 respondents (73.3%) were in agreement that bandwidth management reduce network traffic congestion thus improving data transfer and bandwidth optimization. Figure 1.25 below summarizes the results of table 1.25.

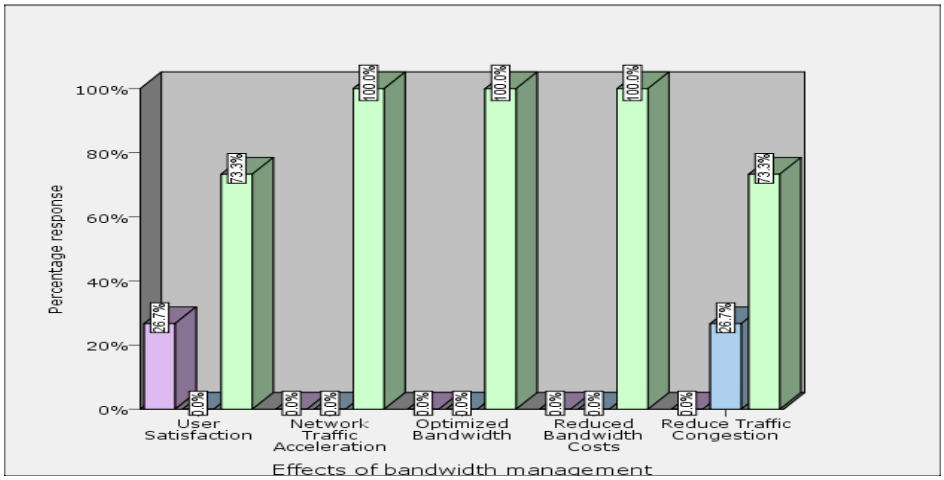


Figure 1.25: Effects of Bandwidth Management

Legend

Disagreement Neutral Agreement

4.7.12 Summary

In this chapter, data analysis methods, study results and research findings have been presented. Findings from this are consistent with the findings of several related studies in techniques for optimizing network utilization and performance. In addition the impact of

various demographic data and respondents leaning towards specific schools and age variance has been explored. Data findings were described as correlations to the study variables and presented as tabulations. The next chapter provides the results interpretation based on the discussions above.

CHAPTER FIVE

INTERPRETATION OF RESEARCH FINDINGS

This chapter interprets and summarizes the results presented in chapter four. The interpretation of the data is based on techniques for optimizing network utilization and performance. In particular, the following details are discussed: bandwidth optimization; query optimization; latency management; network load balancing; internet content filtering; network congestion and congestion control and ICT policies.

5.1 Bandwidth Optimization

Bandwidth optimization is one of the enormous IT challenge that institutions face in today's network. Many institutional networks are not visible and highly constrained with network resources. Network visibility is a prerequisite for successful bandwidth optimization as illustrated in Appendices (G and H). According to (Chitnis, 2014) *Bandwidth increase only solves only an inherent problem of network traffic loads therefore, it is feasible to optimize the existing bandwidth*. Table 1.26 below, shows the frequency and percentages for bandwidth capacity timeline at Kabarak University.

Table 1.26: Bandwidth Capacity Timeline

Year	Mbps
2002-2007	0.256
2008-2009	2
2010-2010	4
2012-2013	28
2014-2015	71
2015-2015	49.2

(Source: Kabarak University 2015)

Figure 1.26, below shows bandwidth capacity timeline for Kabarak University.

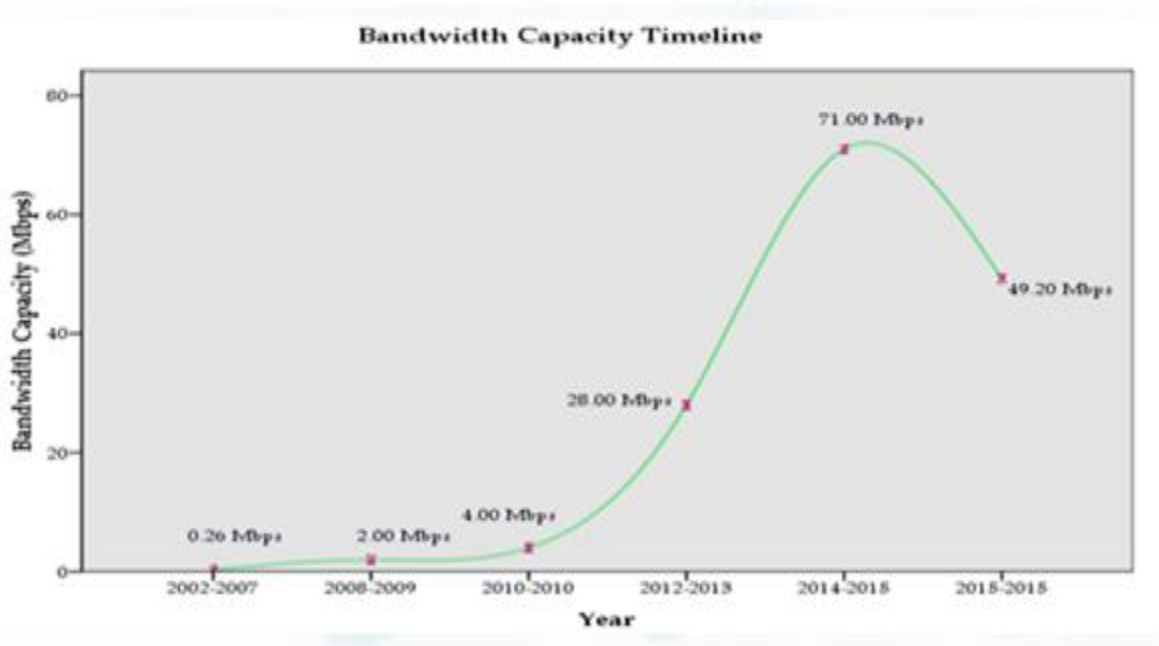


Figure 1.26: Bandwidth Capacity Timeline

From figure 1.26, above, it is conspicuously that the overall bandwidth usage trend is continuously going up starting from 0.26 Mbps to 71 Mbps between 2002 and 2014 period as indicated in the bandwidth capacity timeline. This trend is driven by number of issues; growing number of network users in the institution, increased use of electronic resources and demand for more bandwidth. This upward trend necessitated the need for a solution to this intrinsic problem since it was no longer tenable for the institution to meet bandwidth expense which stood at $35,700 against the budgeted cost of $23,250. In 2015/2016 financial year, the management revised bandwidth capacity from the current 71 Mbps to 49.2 Mbps after bandwidth optimization was done. Table 1.27 summarizes the current recommended bandwidth ratio per user in institutions of higher learning in Kenya.

Table 1.27: Recommended Bandwidth Ratios

Sub-indicator	Sub-indicator value (2013)	Target Sub-indicator value (2015)
Internet bandwidth per 1,000 users	4 Mbps	10 Mbps

(Source: KENET e-readiness data 2013)

The table below show current users population per campus at Kabarak University. The data in table 1.28 plays key role in quantifying bandwidth required, adequacy and ratios per user and campus over a specified period of time.

Table 1.28: Current User Population Data

	Total
MC	4880
NTC	1179
NRB	240
Total	6299

KEY:

MC - Main Campus

NTC - Nakuru Town Campus

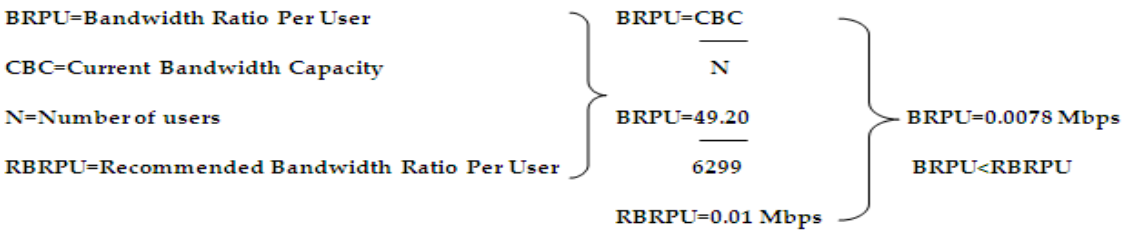
NRB - Nairobi Campus

(Source: Kabarak user's population data 2015)

5.1.1 Kabarak University overall Bandwidth Capacity

The Text box 1.2 below, demonstrates that the overall bandwidth ratio per user stood at 0.0078 Mbps. This shows that the overall bandwidth ratio per user is less than the recommended bandwidth ratio per user of 0.01 Mbps. Therefore, there is an overall deficit of 0.0022 Mbps to meet the recommended bandwidth ratio per user. Text box 1.2 below summarizes the overall bandwidth capacity ratio in comparison with the recommend bandwidth ratio per user.

Text box 1.2: Kabarak University overall Bandwidth Capacity Ratio per User

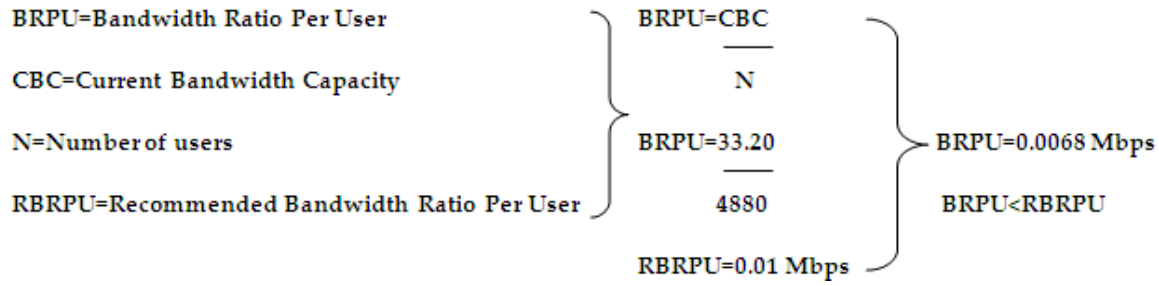


5.1.2 Kabarak University MC Bandwidth Capacity

The Text box 1.3 below shows Kabarak University **MC** bandwidth ratio per user. The bandwidth ratio per user in main campus stood at 0.0068 Mbps which is still is less than the recommended bandwidth ratio per user of 0.01 Mbps. Therefore, there is deficit of 0.0032 Mbps to meet the recommended bandwidth ratio per user in Kabarak University **MC**. This illustrates that Kabarak University main campus needs additional bandwidth of 0.0032 Mbps in order to meet to meet the recommended bandwidth ratio per user.

Text Box 1.3 below summarizes Kabarak University **MC** bandwidth capacity ratio per user.

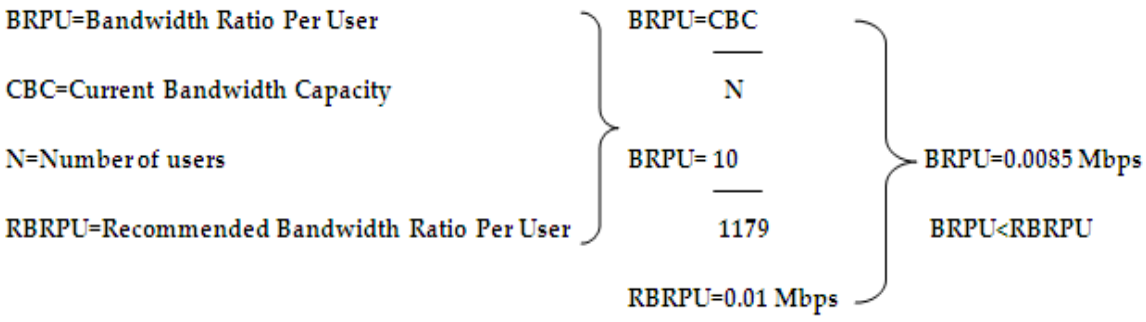
Text Box 1.3: Kabarak University MC Bandwidth Capacity Ratio per User



5.1.3 Kabarak University NTC Bandwidth Capacity

The Text Box 1.4 below shows Kabarak University **NTC** bandwidth ratio per user. The bandwidth ratio per user in **NTC** stands at 0.0085 Mbps which is still is less than the recommended bandwidth ratio per user of 0.01 Mbps. Therefore, there is deficit of 0.0015 Mbps to meet the recommended bandwidth ratio per user in Kabarak University **NTC**. This illustrates that Kabarak University **NTC** requires more bandwidth of 0.0015 Mbps in order to satisfy the recommended bandwidth ratio per user. Text Box 1.4 below summarizes Kabarak University **NTC** bandwidth capacity ratio per user.

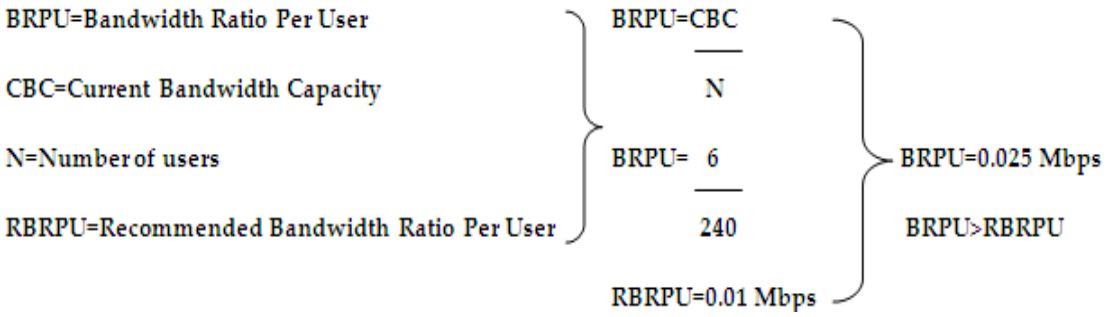
Text Box 1.4: Kabarak University NTC Bandwidth Capacity Ratio per User



5.1.4 Kabarak University NRB Bandwidth Capacity

The Text Box 1.5 below shows Kabarak University **NRB** bandwidth ratio per user. The bandwidth ratio per user in **NRB** stands at 0.025 Mbps which is more than the recommended bandwidth ratio per user of 0.01 Mbps. Therefore, Kabarak University **NRB** does not need bandwidth increase since it meets the recommended bandwidth ratio per user by 0.0015 Mbps. Text Box 1.5 below summarizes Kabarak University **NRB** bandwidth capacity ratio per user.

Text Box 1.5: Kabarak University NRB Bandwidth Capacity Ratio per User



Bandwidth capacity ratios above clearly indicate that network utilization is an absolute necessity to control bandwidth and prioritize network traffic for improved network performance. Adherence to recommended bandwidth capacity ratios plays a critical role in reducing traffic loads across the network that causes unnecessary packet delays. It also helps to improve network performance and data reliability by leveraging on the available bandwidth without the need for increasing more bandwidth which is has become an economic constraint to the institutions of higher learning.

Research findings in this study further shows that bandwidth optimization is the ultimate solution towards improving user's satisfaction and productivity levels by curtailing internet downtimes resulting from inadequate bandwidth usage. It is important to note that without bandwidth optimization, access to critical applications will be highly compromised causing severe interruption of services that impacts the day to day operation activities of the institution. Proxy server delay pools were introduced to curb this problem. Table 1.29 below summarizes the number of popular web sites hits before introduction of squid proxy delay pools bandwidth optimization on daily average.

Table 1.29: Web Site Hits Before Bandwidth Optimization

Variables	*Frequency*	*Percentage*
	(f)	*(%)*
1 YouTube	3136	47.5%
2 Facebook	942	14.3%
3 Google	827	12.5%
4 Twitter	474	7.2%
5 SSL	307	4.6%
6 Image	251	3.8%
7 Avast! Antivirus	184	2.8%
8 Instagram	173	2.6%
9 HTTP	167	2.5%
10 Google Mail (Gmail)	145	2.2%
Total	**6606**	**100.0%**

In figure 1.27 below, demonstrates a scenario where there is absence of prudent bandwidth optimization policies therefore, depicts a network that is running in suboptimal performance. This causes relapse of network resources within the institution resulting to denial-of-service to critical application applications thus interrupting services that impacts daily routine operations. Figure 1.27 below, further shows the changing network traffic patterns and usage among the network users before introduction squid proxy delay pools.

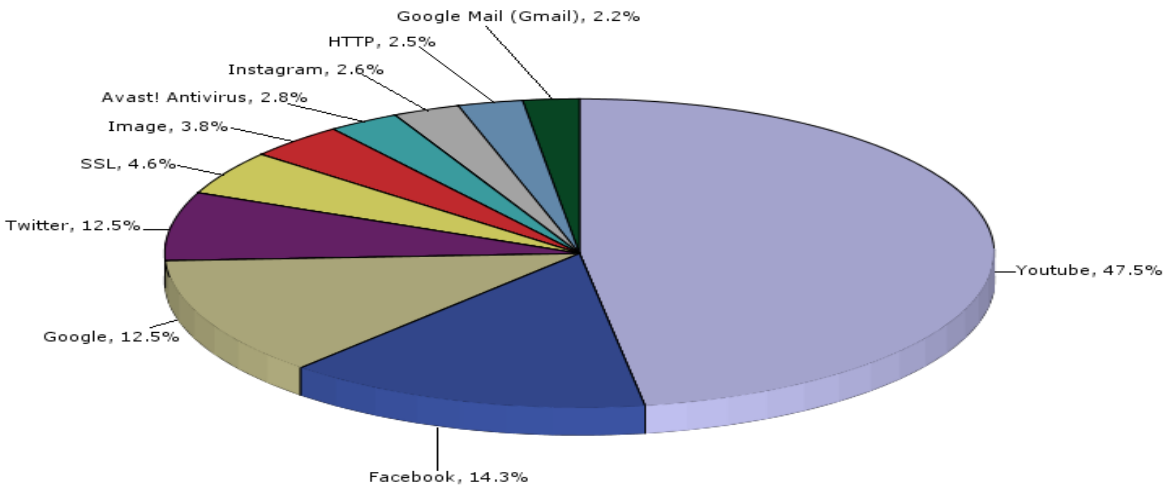


Figure 1.27: Before Bandwidth Optimization

The Table 1.30 below summarizes the number of popular web sites hits after introduction of squid proxy delay pools bandwidth optimization on daily average.

Table 1.30: Web Site Hits After Bandwidth Optimization

Variables	*Frequency*	*Percentage*
	(f)	*(%)*
1 Google	1105	16.7%
2 Avast! Antivirus	1063	16.1%
3 HTTP	971	14.7%
4 SSL	968	14.7%
5 Google Mail (Gmail)	679	10.3%
6 YouTube	623	9.4%
7 Facebook	544	8.2%
8 Twitter	374	5.7%
9 Student-Portal	142	2.1%
10 Instagram	137	2.1%
Total	**6606**	**100.0%**

In figure 1.28 below, demonstrates a scenario where network policies are enforced to enable reasonable distribution of network resources and optimized network performance. The results in figure 1.28 illustrates that bandwidth optimization is a basic necessity in addressing inadequacies of bandwidth utilization and uneconomical use of network resources in institutions. It is notable that there is no point where bandwidth size will be sufficient enough to meet institutional needs therefore, bandwidth optimization is critical. Bandwidth optimization reduces significantly cost of bandwidth as well as minimizing bandwidth demands by eliminating costly bandwidth upgrades. Additionally, bandwidth optimization reshapes and grooms network traffic to maximize use of the available bandwidth.

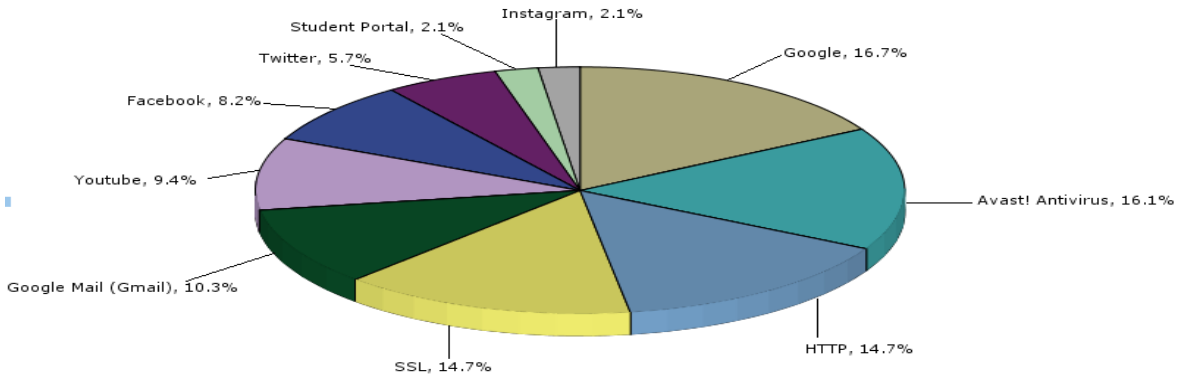


Figure 1.28: After Bandwidth Optimization

5.2 Query Optimization

Query optimization is process of choosing an optimal query execution plan with minimum cost. Query optimization reduces substantially the amount of data that a query processes therefore, reducing the time required to transmit a query and display query result. Query optimization plays important role in increasing network throughput where usable bandwidth is limited by optimizing query response time ensuring efficient

utilization of network resources. This helps to reduce bandwidth demands hence a cost-saving strategy. The results in Chapter four of this research study summarizes impacts of query optimization. Cacti tool was used to summarize query statistics. Cacti tool uses Round-Robin Database tool to store the polled data and create actual performance graphs of student/staff portal server. The graphs generated by Cacti tool was used to visualize network traffic activity, MySQL statistics and test the efficiency of query optimization strategies deployed in students/staff portal server.

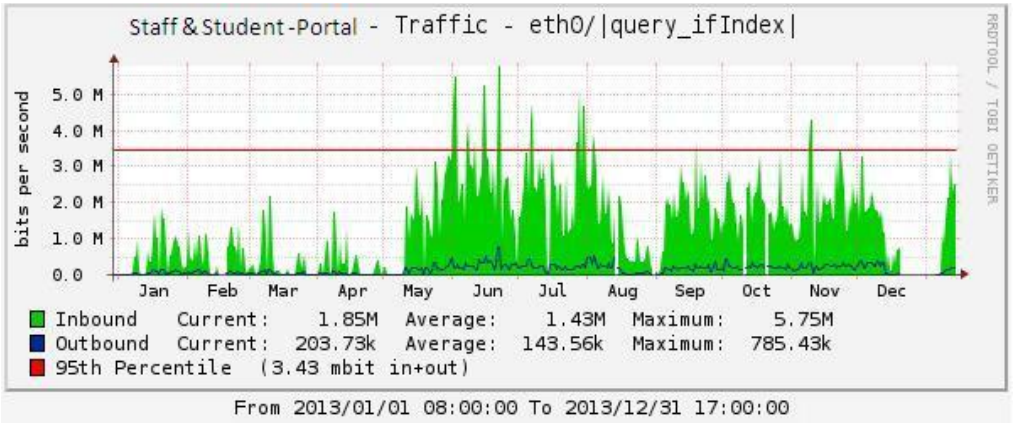


Figure 1.29: Before Query Optimization

The results in Figure 1.29 above demostrates network traffic statistics of staff/student portal before query optimization was done for yearly average. Figure 1.29 above received less inbound and outbound network traffic between the period of January and April. This significant drop in network traffic between the month of January and April is attributed to existence of suboptimal queries that causes packet losses and latencies. Furthermore, network traffic between the period of May and December was experiencing high flactuations due to network traffic jitters resulting to uneven network traffic patterns. The maximum inbound traffic hit at 5.75 Mbps mark while the minimum outbound traffic hit at 785.43 Kbps mark. This demostrates a deficiency in query optimization strategies that

leverages on both inbound and oubound network traffic of students/staff portal server causing performance regressions.

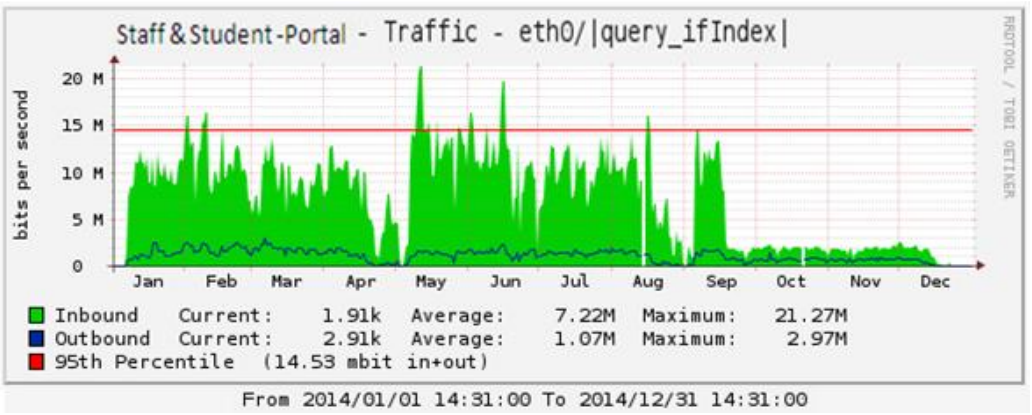


Figure 1.30: After Query Optimization

The results in Figure 1.30 above demostrates network traffic statistics and query utilization pattern of staff/student portal after query optimization was done for yearly average. From the results in figure 1.30 above, it is evident that there is steady rise in inbound and outbound network traffic. Figure 1.30 further demostrates a significant drop in network traffic in April, August and December. This drop of network traffic activity between the months April, August and December was occassioned by students vacation holidays. The maximum inbound traffic stood at 21.27 Mbps mark while the minimum outbound traffic hit at 2.97 Mbps mark. This shows major increase in network traffic in figure 1.30 compared to results in figure 1.29 respectively. From figure 1.30 above, it is apparent that students/staff portal performance has improved immensely due to effective query optimizations and utilizations strageties deployed.

5.3 Latency Management

Latency is one of biggest problem that slow web applications across the network. Latency causes propagation delays in the network leading to network congestion, jitter and packet loss. This affects response times of web applications and depletes usable bandwidth meant for other critical applications. Latencies experienced in any networks are intermittent and momentary hence can be managed. Latency management addresses these issues by using effective strategies like proxy logrotate which frees more caching and prefetching space hence mitigating effects of network latency. This strategy reduces retransmission of amount of data traffic across the network by compressing recently accessed log files and removal of old log files which are not frequently accessed or referenced therefore, latency managed, equates to additional usable bandwidth and cost saved. SmokePing tool was used to probe servers for any kind network latency. SmokePing uses RRDtool to log traffic sessions and generate statistical graphs and charts. Round-Robin Database tool (RRDtool) captures time-series data (successive measurements made over a time interval) to probe servers for any form of latency. SmokePing helps network administrators to figure out latencies and performance degradation on network links. SmokePing was used to probe proxy servers for packet losses that translate to latencies in the network. Latency measurement is extremely important since it provides the much need information to network administrators in managing network throughput. Figure 1.31 below shows Internet Control Message Protocol (ICMP) echo request packets perfomed on students proxy server with a polling interval of 5 minutes (300s) over a period of 360 days.

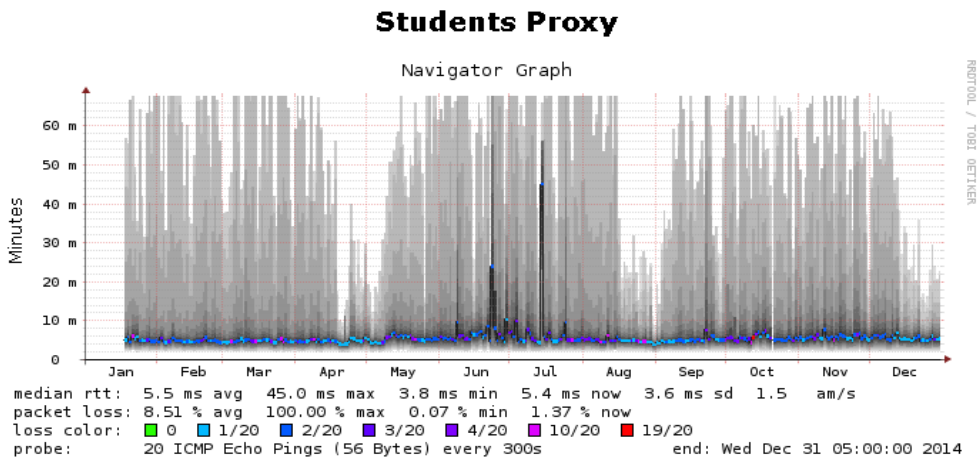


Figure 1.31: Results Obtained from Students Proxy Server Ping Latency Probe

Figure 1.31 above shows Internet Control Message Protocol (ICMP) echo request packets performed on students proxy server with a polling interval of 5 minutes (300s) for a period of 360 days. The results in Figure 1.31 above demostrates significant drop in overall latency and packet losses between the period of January and December 2014 in students proxy server. This shows that students proxy server is currently experiencing minimal packet percentage losses and low jitters. The yearly average packet loss stood at 8.51% and the minimum current average loss stood at 1.37% in students proxy server as shown in figure 1.31 above. This is as a result of proactive latency monitoring and management as illustrated by loss color and network traffic patterns in figure 1.31 above. The results from figure 1.31 further, shows a significant drop on observed network traffic patterns during the months of April,August and December. This is attributed to students vacation break that occurs between the months of April,August and December thus less network traffic.

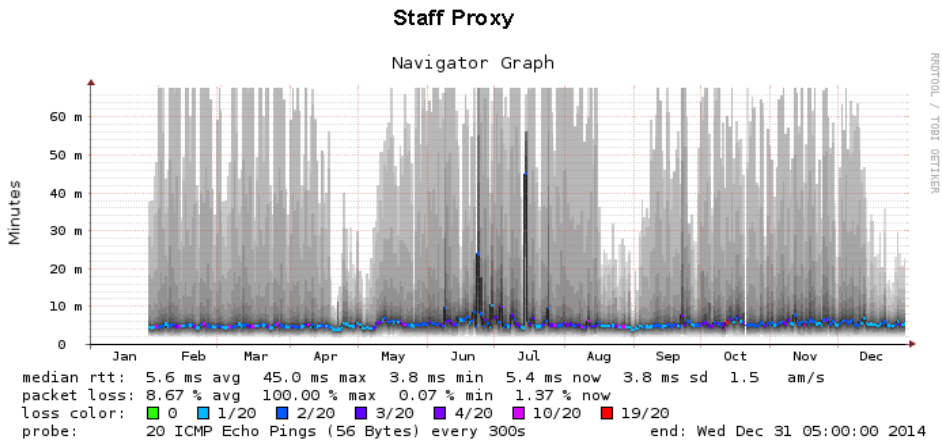


Figure 1.32: Results Obtained from Staff Proxy Server Ping Latency Probe

Figure 1.32 above shows Internet Control Message Protocol (ICMP) echo request packets performed on staff proxy server with a polling interval of 5 minutes (300s) for a period of 360 days. The results in Figure 1.32 above shows a considerable drop in general latency and packet losses between the period of January and December 2014 in staff proxy server. This can be attributed to effective network monitoring strategies deployed resulting to consistent network traffic patterns as illustrated in figure 1.32 above. The yearly average packet loss stood at 8.67% and the minimum current average loss stood at 1.37% in staff proxy server as shown in figure 1.32 above. The results from figure 1.32 shows a relatively slight drop on observed network traffic patterns during the months of April,August and December due to students vacation break hence less network traffic activity within these months.

5.4 Network Load Balancing

Network load balancing is a networking strategy used to distribute traffic workloads across several servers to ensure scalability, reliability and availability of network resources. This ensures optimization of network resources and increased response time of

applications by scaling down the number of traffic loads in servers thus freeing more network resources and increasing the amount of usable bandwidth. Moreover, network load balancing plays critical role in providing network redundancy so that incase of any service link unavailability, users can still access network resources through other servers across the network. Cacti tool was used to probe proxy servers to determine the average load. Figure 1.33 and figure 1.34 below shows students proxy server and staff proxy server yearly load average probe respectively.

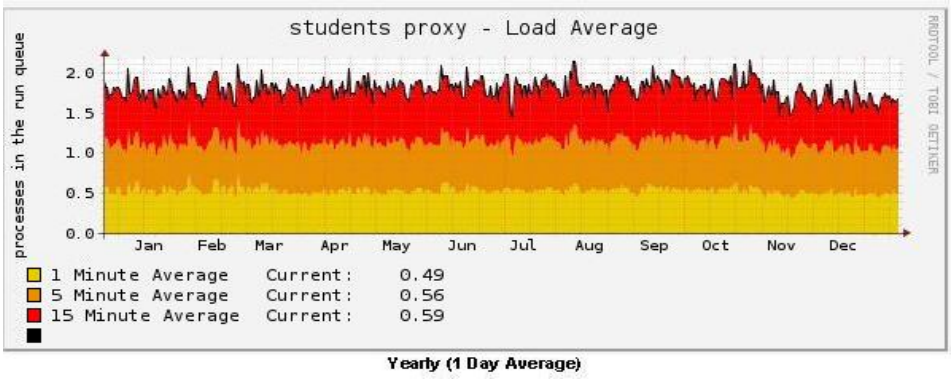


Figure 1.33: Results Obtained from Students Proxy Server –Load Average Probe

Figure 1.33 above shows students proxy server yearly load average probe with a polling interval of 1 ,5 and 15 minutes for a period of 360 days. The results in Figure 1.33 above shows a consistent network load average pattern for students proxy server. This is attributed to efficient ways of load balancing set out to mitigate network hiccups occassioned by heavy traffic loads that reduces network optimability and performance. From the results in figure 1.33 it is clear that network load balancing provides the needed balance and even distribution of network workloads and resources in proxy servers.

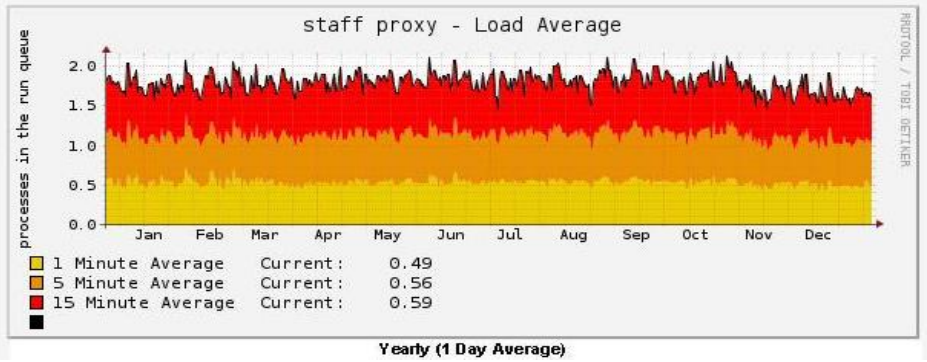


Figure 1.34: Results Obtained from Staff Proxy Server –Load Average Probe

Figure 1.34 above shows staff proxy server yearly load average probe with a polling interval of 1 ,5 and 15 minutes for a period of 360 days. The results in Figure 1.34 above shows a even network load average pattern for staff proxy server. The results in figure 1.34 above, shows that network load balancing is one of key components in regulating and managing proxy server loads across the network through traffic distribution. This ensures optimal utilization of network resources. From the results in figure 1.34 it is clear that network load balancing provides the needed balance and even distribution of network workloads and network resources in proxy servers.

5.5 Network Performance Monitoring

Network congestion is an inherent network problem that occurs across the network where several users compete for access to the same resources leading to service deterioration thus lower throughput. This occurs when bandwidth demands exceeds its threshold capacity causing packet losses and network delays occasioned by networks without end-to-end visibility. Network performance monitoring allows network administrators to determine how data packets are transmitted across the network based on predefined priorities. This helps network administrators to monitor network traffic loads ensuring

that network quality of service is not compromised. Nagios tool was used to probe network performance in proxy servers. Nagios tool is open source software under GPL v2.0. Nagios monitors entire network performance to identify critical network breakdowns in advance and mitigate them before affecting end users (Barth, 2008). Nagios tool was used to probe proxy servers to determine the state of network breakdowns and performance degradation across the network. The graphs generated by Nagios tool was used to visualize network performance of network devices as demonstrated in Figure 1.35 and Figure 1.36 below respectively.

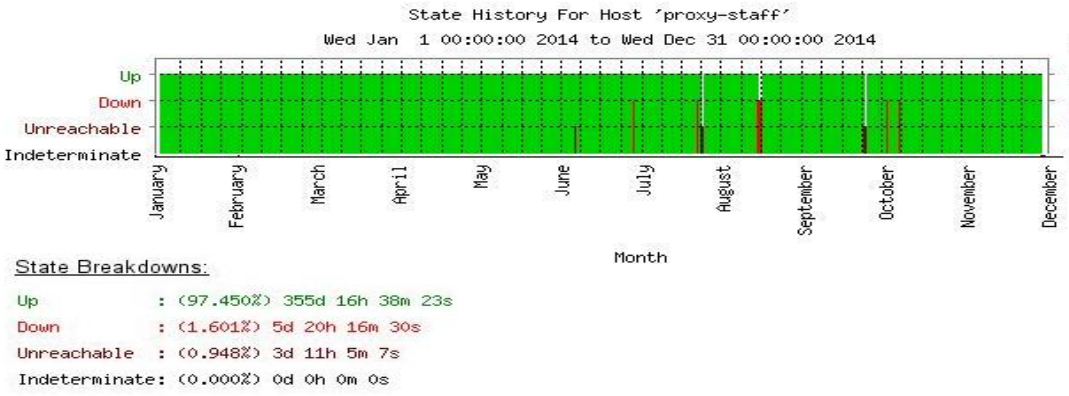


Figure 1.35: Staff Proxy Server – Network Performance and Availability Probe

Figure 1.35 above, shows staff proxy server monthly network performance and availability for a period of 12 months. The results in Figure 1.35 above reported (97.450%) uptime within a period of 12 months. This is attributed to effective network monitoring strategies that proactively detect and troubleshoot network problems in advance hence service availability. The results further reported a downtime of (1.601%) and unreachable status of (0.984%) in staff proxy within the same period of time. These network outages can be attributed to routine maintenance of proxy server and prolonged power outages where alternative power backup is completely drained . From the results in Figure 1.35 it is clear that network performance monitoring plays an active role in ensuring that there is minimal service degradation across the network.

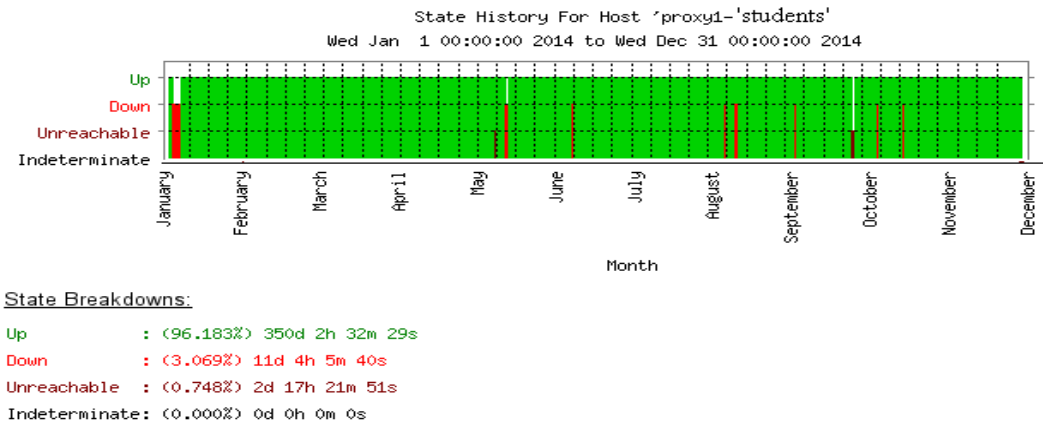


Figure 1.36: Students Proxy Server – Network Performance and availability Probe

Figure 1.36 above, illustrates students proxy server monthly network performance and availability for a period of 12 months. The results in Figure 1.36 above reported (96.183%) uptime within a period of 12 months. This is attributed to effective network monitoring techniques that helps network administrators to resolve network hitches affecting the network. The results further reported a downtime of (3.069%) and unreachable status of (0.748%) in students proxy within the same period of time. These network outages can be attributed to routine maintenance of proxy server and prolonged power outages where alternative power backup is completely drained.

5.6 Web Traffic and Content Filtering

Web Traffic control and content filtering are essential techniques used to moderate internet content. Content filtering is policy issue where users sign Service Level Agreement with the institution on acceptable standards on internet use. Many institutions and organizations have formulated policies in regulating internet content based on their business interests. Content filtering censors unnecessary internet traffic rendering them inaccessible. With Content Filtering Service, institutions set their own security policies to

be obeyed in order to prevent bandwidth intensive applications from gobbling down the available bandwidth. Content Filtering Service protects wide area network, local network area an virtual private network links from web based-threats and enforces other security policies that are line with institutional policies. Content Filtering Service allows network administrators to filter out inappropriate content which hinders quality of service delivered to end-users. Content Filtering Service caches acceptable URL rating sites (SonicWALL, 2014). This reduces significantly the response time for frequently accessed sites enhancing network performance and bandwidth utilization. Moreover, Content Filtering Service plays additional role in educating users and raising level of user awareness on best practices in optimizing network utilization and performance. Port filtering is another best practice utilized to insulate web servers against SYN flood requests. IIS port reconfiguration from default port to a different port reduces vulnerability of web servers against SYN flood requests thus mitigates denial of service attacks hence enhance improved Quality of Service.

5.7 ICT Policy

ICT policy is master plan that guides ICT development, accessibility and utilization of network resources. The rationale behind ICT policy in institutions of higher learning is to deal with issues of bandwidth optimization and utilization of network resources in accordance to core principles of the institution. ICT Policy takes a holistic approach in addressing problems of network utilization and performance through policy-based approach. Policy-based approach defines set of rules that guide network administrators in prioritizing network resources. Network traffic analysis of users behavioral and usage patterns provides the key aspect in formulating effective policies that runs in tandem with

ICT Policy. The results in figure 1.24 show that more than half of the respondents acknowledged the presences of ICT policy as illustrated in Figure 1.24. This is attributed to level of user awareness on the existence of network utilization policies. This fact is further supported by the statistics in figure 1.25 where (77.8%) of the respondents were in agreement that the current ICT Policy supports network utilization and performance therefore; ICT Policy is a fundamental component that takes holistic approach in optimizing network utilization and performance through policy-based network access policies that are aligned in accordance to standards set in ICT policy.

5.8 Summary

From the interpretation of the empirical findings of this research study, it is clear that the current techniques for optimizing network utilization and performance as practiced in institutions of higher learning in Kenya are deemed reasonably effective. However, these techniques need review in order to enhance effectiveness of network utilization and performance. Firstly, the findings have indicated clearly that bandwidth increase only reduces traffic loads therefore, bandwidth optimization is critical. The findings further shows that the efficiency of query throughput enhances both inbound and outbound traffic hence increased network performance. Moreover, proactive network monitoring mitigates effects of network latencies thus ensuring network performance is at its peak. The research findings further show that policies have serious influence on the network performance. It throttles unnecessary network traffic that causes congestion within the network. Furthermore, policies enhance user awareness on the importance of bandwidth optimization. The next chapter provides the conclusions and makes recommendations based on the above research findings.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

This chapter summarizes the thesis research and suggests research and policy recommendations for further analysis. This was done with reference to the aim of the research study which was to critically examine the current state of bandwidth usage and network utilization at Kabarak University in order to propose effective strategies for optimizing network utilization and performance. The research findings of this research are based on the data collected and presented in chapter four. The data was collected using questionnaires referenced in **Appendices (B, C)**. The data were presented in form of figures (percentages), tables, graphs and charts with narrative statements for interpretation in chapter five. The conclusions given were drawn from the outcomes of the research and observations on network utilization and performance. Furthermore, the recommendations outlined were based from the research findings of this research study.

6.2 Conclusion

This research study focused on network utilization and performance at Kabarak University. From the empirical findings of this study suggest that latency management is the most critical and best practice for efficient network utilization and performance in institutional networks. Latency management mediates the effect network performance by keeping network latencies in check and provide insights to network administrations to know real-time and historical information on usage and performace. Moreover, it helps network administrators to pre-empt network latencies problems proactively before users

start logging their complains therefore, assist in planning ahead on institutional bandwidth needs and ensuring availability of network resources with minimal downtimes.. According (Rash, 2010) latency controlled, means more usable bandwidth and a cost saved.

The findings further suggest how important it is for institutions to mitigate network risks proactively through network visibility which deliver real value of optimized quality of service and acceptable level of user satisfaction. Without good network visibility, it becomes difficult to troubleshoot problems in the network therefore, the Estimated Time of Return will be long hence compromises quality of service as summarized by (Plant, 2014) *"if you are unable to see what is happing on your network then you will not be able to control it'*.

The results of the finding further suggests that in order to achieve better network utilization and performance, institutions should adopt proxy load balancing to reduce network traffic loads. Proxy load balancing was used to distribute traffic workloads across several servers to ensure increased response time of applications by scaling down the number of traffic loads in proxy servers hence liberate more network resources. Therefore, proxy load balancing plays critical role in providing network redundancy incase of any service link degradation. In addition, the finding shows that adherence to recommended bandwidth capacity ratios leverages network utilization and available bandwidth therefore, rationalizes IT costs. In order to obtain better service delivery, industry recommended bandwidth capacity ratios must be adhered to towards improving user's satisfaction and productivity levels resulting from inadequate bandwidth ratios and

usage. From the empirical findings of this study suggest that query optimization enhances response time of query results and network performance therefore, ease bandwidth demands which in turn save costs hence acceptable means in addressing bandwidth inadequacies at Kabarak University.

Finally, the research findings suggest that institutions must adopt holistic approaches towards enhancing network utilization and performance. Proactive network performance monitoring is one of the key approach used to benchmark for an effective network utilization and performance. Proactive network performance monitoring is an efficient utilization strategy in identifying faults in networks prior to its manifestation therefore, helps network administrators to figure out and diagnose network problems that impede on network effectiveness. Proactive network performance monitoring reduces significantly downtime and service degradation by eliminating network bottlenecks across the network. Moreover, ICT policy another key effective strategy used in network utilization and performance. According (Sharma, 2011, pp. 173-178) policy based network utilization approach improves network utilization and performance therefore; ICT policy that is geared towards optimizing network utilization and performance is of great importance. Content filtering service is another policy issue which can be aligned with ICT policy. Content filtering service enables institutions to set their own security policies that prevent bandwidth-intensive applications. This allows painless enforcement of network usage policies as set in ICT policy. From the research findings we can therefore, conclude that enforced ICT policies are best strategies in optimizing network resources and performance. Policies ensure best practices of network usage are adhered by end-users.

6.3 Recommendations

This section addresses on the recommendations to system administrators, network administrators, University management and other relevant stakeholders on better ways of improving network utilization and performance. In light of the research findings of this study, the following recommendations are made for the intention of enhancing strategies for optimizing network utilization and performance at Kabarak University. The recommendations that follow are derived from the conclusions of this research study:

i. Given the evolving nature of networks and its complexity, network and system administrators should focus on baselining and trending of network resources in order to prevent disruption of key institutional services.

ii. Network and system administrators should work in hand with university management to re-evaluate the current ICT policy to incorporate robust strategies that sets acceptable standards that govern network access and usage policy.

iii. ICT support staff should raise user awareness among all stakeholders on appropriate use of network resources must be prioritized and should be carried out in accordance to procedures laid down in the ICT policy.

iv. Network administrators should focus on network infrastructure redesign by replacing CAT5 UTP cables with CAT6 UTP cables.

v. Proactive network management and Service Level Agreement enforcement by system administrators.

vi. University management should invest on the right tools for enforcing policies and network utilization.

6.4 Suggestions for Further Research

The research that has been carried out has underlined a number of issues which requires further research to be conducted. Although this research study has tried to address the issues of optimizing network utilization and performance at Kabarak University, others still remain to be addressed. For that reason, further research would be beneficial.

i. In order to broaden the scope of this research study, future researchers should target more institutions of higher learning in Kenya. Their input will be of great importance in improving network utilization and performance strategies.
ii. Further research on network rightsizing should be conducted to determine the level of network utilization and performance trade offs.
iii. Future studies can focus on bandwidth recycling as a strategy of optimizing network utilization and performance.

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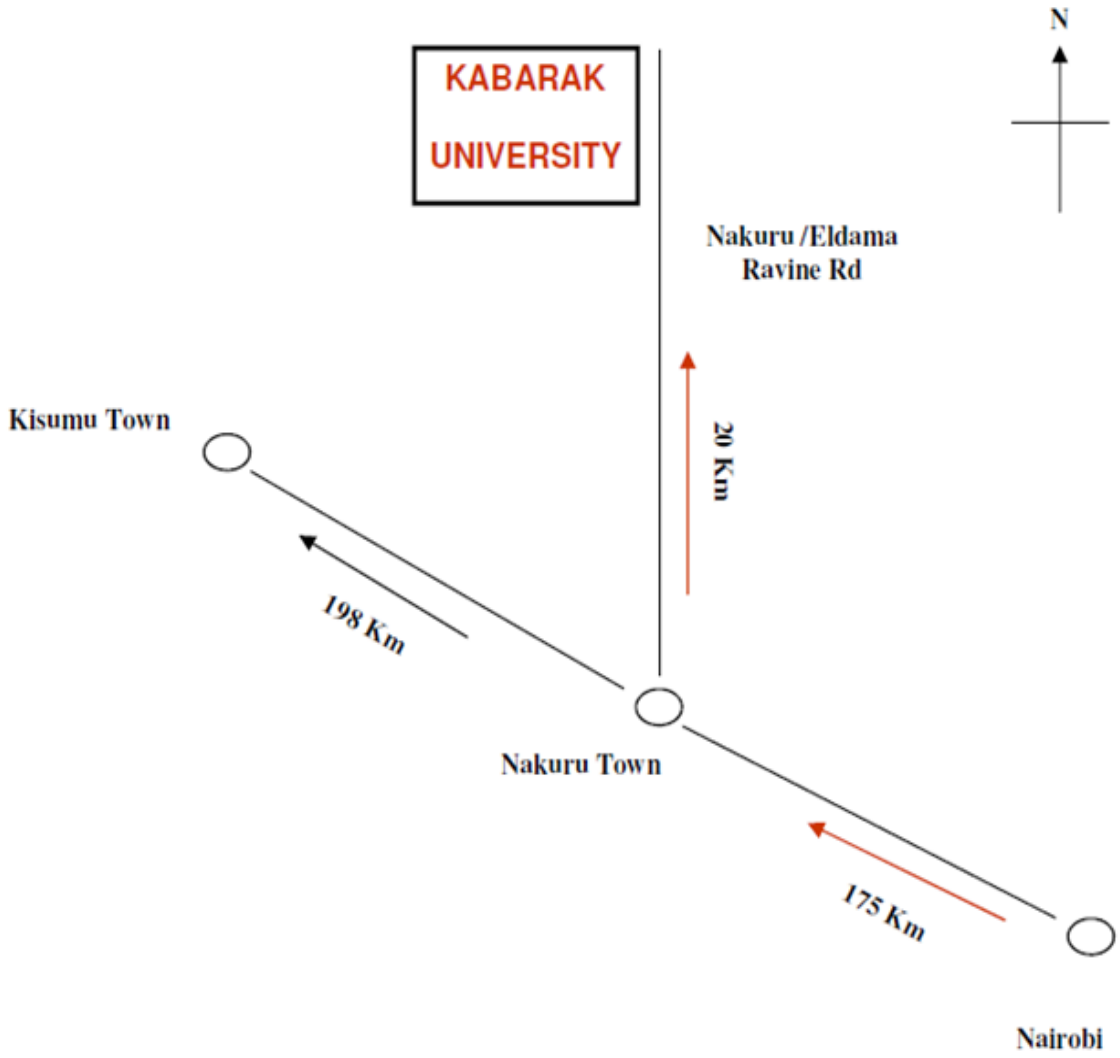
APPENDICES

APPENDIX A: GEOGRAPHICAL LOCATION



APPENDIX B: STUDENTS QUESTIONNAIRE

Dear respondent,

I am student at the School of Information Sciences, Moi University undertaking research thesis on "Design Techniques for Optimizing Network Utilization and Performance at Kabarak University". This questionnaire is issued purely for academic purpose and the information provided will be treated with utmost confidentially. Your cooperation will be highly appreciated. Thanks in advance.

Tarus Kiptum Silah

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QUESTIONNAIRE FOR STUDENTS

I am student at the School of Information Sciences, Moi University undertaking research thesis on Design Techniques for Optimizing Network Utilization and Performance at Kabarak University. This questionnaire is issued purely for academic purpose and the information provided will be treated with utmost confidentially. Your cooperation will be highly appreciated. Thanks in advance.

Tarus Kiptum Silah

Section A: Background information

1. What is your gender? *

- [ ] Female
- [ ] Male

2. What is your age? *

- [ ] 0-18 years.
- [ ] 19-30 years.
- [ ] 31-45 years.
- [ ] 46 years and above.

3. Name of institution: *

KABARAK UNIVERSITY MAIN CAMPUS

4. SCHOOL *

SCHOOL OF BUSINESS

5. Department: *

Business Studies

6. Year of study: *

1

7. Semester: *

1

8. Area of specialization: *

Page 2 After page 1 Go to page 2 (SECTION B: Managing Bandwidth)

SECTION B: Managing Bandwidth

9. Please state institution, period and level of training in computers, if any: Institution:

10. How many hours on average do you spend on a internet per week? *
Number Of Hours

- [ ] 0 – 9
- [ ] 10 – 19
- [ ] 20 - 29
- [ ] 30 - 39
- [ ] 40 +

11. On average, how many hours do you spend on the following sites at Kabarak University? *
Hours spent on sites stated below

	0-9	10 – 19	20 – 29	30 – 39	40 +
Kabarak Website (student portal)	○	○	○	○	○
Search Engines	○	○	○	○	○
Social Networks	○	○	○	○	○

	0-9	10 – 19	20 – 29	30 – 39	40 +
Academic Research Sites	○	○	○	○	○
General Browsing	○	○	○	○	○
Others	○	○	○	○	○

12. To what extend do you agree with the methods used in managing bandwidth at Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Quality of Service (QoS)	○	○	○	○	○
Caching and Prefetching	○	○	○	○	○
Compression	○	○	○	○	○
Load Balancing	○	○	○	○	○
Distributed Content	○	○	○	○	○

13. Do you agree that managing bandwidth by filtering internet content in Kabarak University amounts to the following issues? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
User Satisfaction	○	○	○	○	○
Out- of –Order-Delivery	○	○	○	○	○
Internet Monitoring	○	○	○	○	○
Restriction on information flow	○	○	○	○	○
Content Availability	○	○	○	○	○

Page 3 After page 2 Go to page 3

14. In your view, what are the challenges of internet and intranet access at Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Slow Connection	○	○	○	○	○

	1	2	3	4	5
Service Disruptions	◯	◯	◯	◯	◯
Internet Downtimes	◯	◯	◯	◯	◯
Service Access Denied	◯	◯	◯	◯	◯
Download Delays	◯	◯	◯	◯	◯

15. What access type do you use when accessing internet and intranet at Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Local Area Network (LAN)	◯	◯	◯	◯	◯
Wireless	◯	◯	◯	◯	◯
Modem	◯	◯	◯	◯	◯
Mobile	◯	◯	◯	◯	◯

16. In your opinion, do you know any strategies used for effective network utilization in Kabarak University? *

◯ YES

◯ NO

If YES, List the strategies you know?

17. What impact will bandwidth management have on access of internet and web based applications in Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Content availability	◯	◯	◯	◯	◯
Reduces latencies	◯	◯	◯	◯	◯
Improves efficiency	◯	◯	◯	◯	◯

	1	2	3	4	5
Academic Performance	◯	◯	◯	◯	◯

18. What impact does bandwidth management have on network security in Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Network Trustworthy	◯	◯	◯	◯	◯
Network Transparency	◯	◯	◯	◯	◯
Reduced Network Traffic	◯	◯	◯	◯	◯

APPENDIX C: STAFF QUESTIONNAIRE

Dear respondent,

I am student at the School of Information Sciences, Moi University undertaking research study on "Design Techniques for Optimizing Network Utilization and Performance at Kabarak University". Information provided will be treated with utmost confidentially. Your cooperation will be highly appreciated.

Thanks in advance.

Tarus Kiptum Silah

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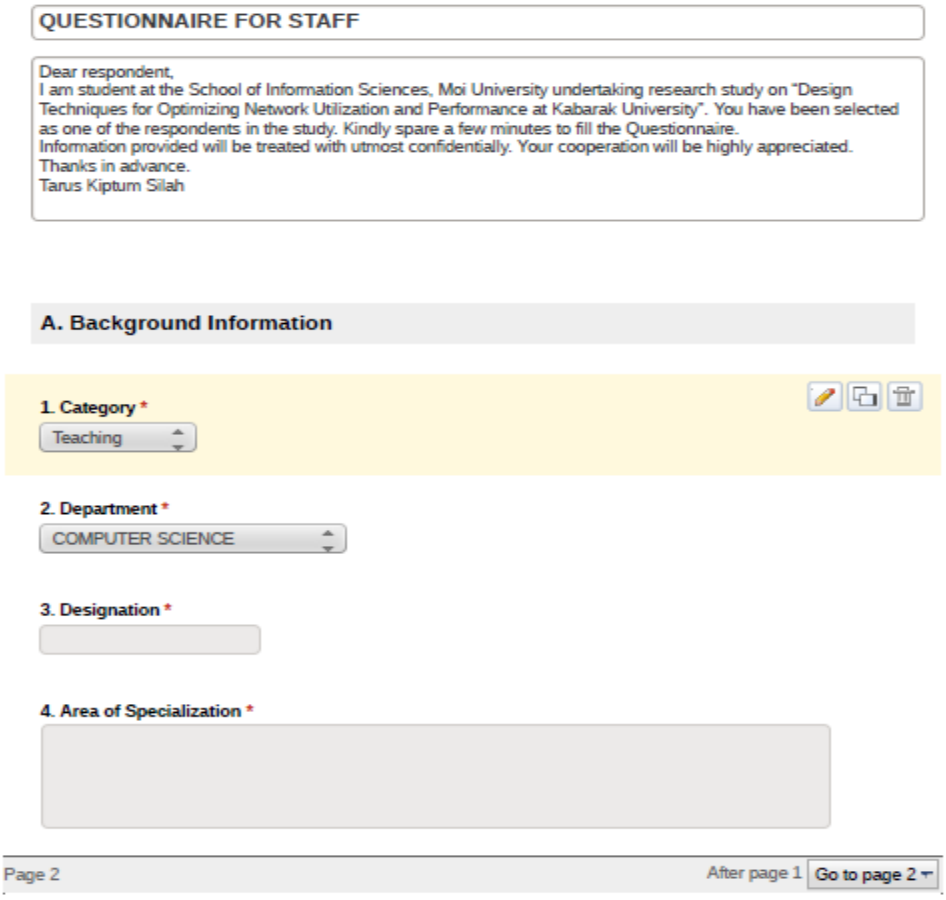

QUESTIONNAIRE FOR STAFF

Dear respondent,
I am student at the School of Information Sciences, Moi University undertaking research study on "Design Techniques for Optimizing Network Utilization and Performance at Kabarak University". You have been selected as one of the respondents in the study. Kindly spare a few minutes to fill the Questionnaire.
Information provided will be treated with utmost confidentially. Your cooperation will be highly appreciated.
Thanks in advance.
Tarus Kiptum Silah

A. Background Information

1. Category *
Teaching

2. Department *
COMPUTER SCIENCE

3. Designation *

4. Area of Specialization *

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SECTION B: Managing Bandwidth

5. To what extend do you agree with the techniques used for network utilization and optimization in Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Caching	◯	◯	◯	◯	◯
Prefetching	◯	◯	◯	◯	◯
Compression	◯	◯	◯	◯	◯
Traffic Management (QoS)	◯	◯	◯	◯	◯
Proxy Substitution	◯	◯	◯	◯	◯
Traffic Distribution	◯	◯	◯	◯	◯
Content Filter Service (CFS)	◯	◯	◯	◯	◯

6.Do you agree with the following strategies in improving content in web-based applications at Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Continuous improvement	◯	◯	◯	◯	◯
Application Development	◯	◯	◯	◯	◯
Content Delivery Networks	◯	◯	◯	◯	◯
Bandwidth Upgrades	◯	◯	◯	◯	◯
Server Upgrades	◯	◯	◯	◯	◯
Infrastructure Upgrade	◯	◯	◯	◯	◯

7. What extend do you agree to the use web-based applications to streamline operations internally at Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Convenience	◯	◯	◯	◯	◯

	1	2	3	4	5
Maintenance	◯	◯	◯	◯	◯
Cost	◯	◯	◯	◯	◯
Security	◯	◯	◯	◯	◯
Deployment	◯	◯	◯	◯	◯
Cross platform compatibility	◯	◯	◯	◯	◯

8. What are the best practices in attaining proxy server load balancing in Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Reverse proxy Severs	◯	◯	◯	◯	◯
Network Address Translation (NAT)	◯	◯	◯	◯	◯
Distributing Network Traffic	◯	◯	◯	◯	◯
Proxy servers firewalls	◯	◯	◯	◯	◯
Content Filter Service (CFS)	◯	◯	◯	◯	◯

9. Which strategies are in place in decongesting network traffic in Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Fibre Optic Termination	◯	◯	◯	◯	◯
Virtual Private Network	◯	◯	◯	◯	◯
Proxy & Application Servers Distribution	◯	◯	◯	◯	◯
Traffic Prioritization & Grooming	◯	◯	◯	◯	◯
Forward error correction (FEC)	◯	◯	◯	◯	◯

10. What strategies does Kabarak University use in query optimizations as a measure to optimize and utilize network? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
SQL Query Tuning	○	○	○	○	○
Query Indexing	○	○	○	○	○
Clustering	○	○	○	○	○
Server Tuning	○	○	○	○	○
De-normalization	○	○	○	○	○
Tables Partitioning	○	○	○	○	○

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11. Which techniques does Kabarak University use in achieving high throughput in regard to query optimizations? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Query Restructuring	○	○	○	○	○
Query Simplification	○	○	○	○	○
Query Indexing	○	○	○	○	○
Virtual Private Network	○	○	○	○	○
High Performance Servers	○	○	○	○	○

12. What strategies are available in attaining low network latencies in Kabarak University? *

1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
Bandwidth Upgrade	○	○	○	○	○
Network Traffic Shaping	○	○	○	○	○
Limiting Proxy firewall rules	○	○	○	○	○
Network Address Translation(NAT)	○	○	○	○	○

13. Do you have any ICT policy at Kabarak University? *

(Please mark check in one of the boxes).

- [ ] YES
- [ ] Not Sure
- [ ] NO

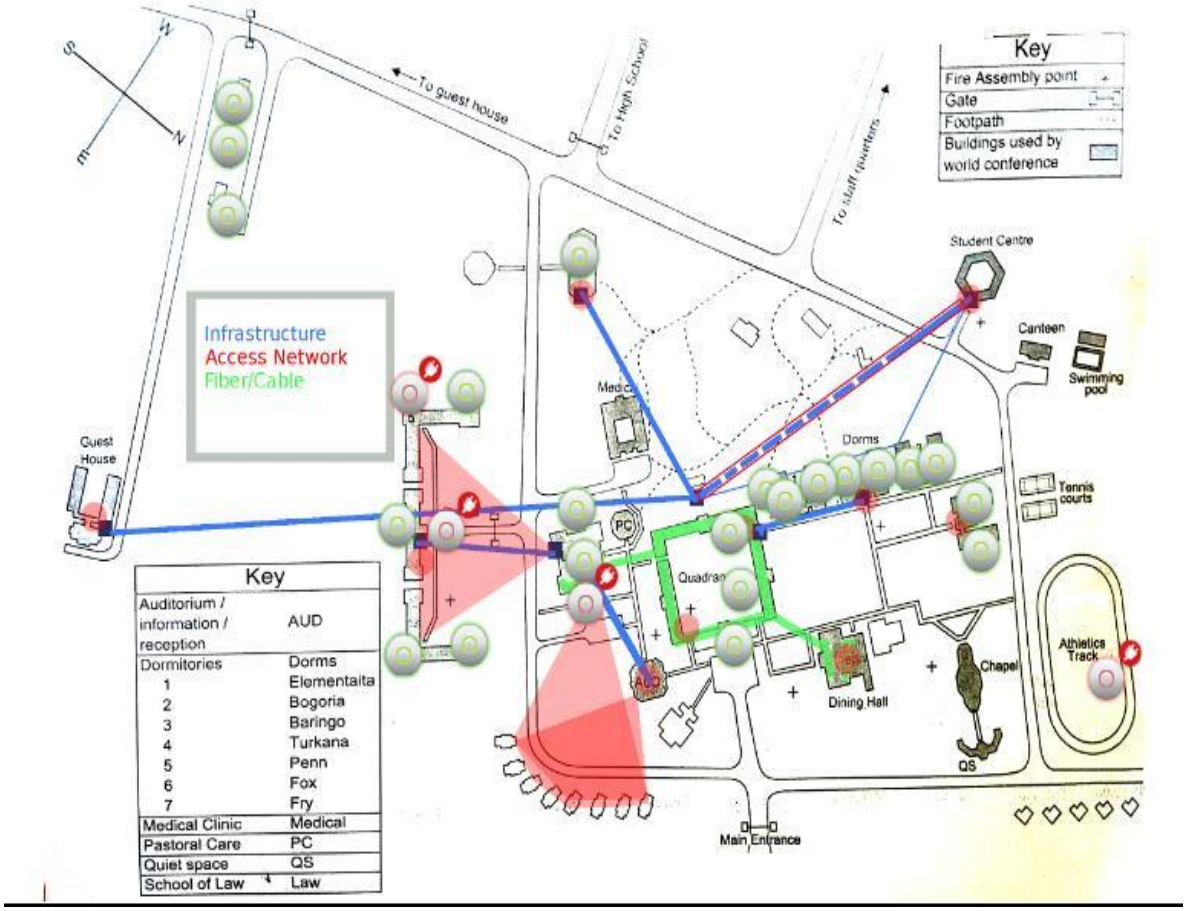
14. If (Yes), Does the ICT Policy support Bandwidth Management in Kabarak University?
(Please mark check in one of the boxes).

- [ ] YES
- [ ] Not Sure
- [ ] NO

15. Do you agree that bandwidth managements in Kabarak University amounts to the following issues? *
1. Strongly Disagree 2.Disagreee 3. Undecided 4. Agree 5. Strongly Agree

	1	2	3	4	5
User Satisfaction	○	○	○	○	○
Accelerate Network Traffic	○	○	○	○	○
Optimized Bandwidth	○	○	○	○	○
Reduced Bandwidth Costs	○	○	○	○	○
Reduced Traffic Congestion	○	○	○	○	○

APPENDIX D: KABARAK UNIVERSITY NETWORK TOPOLOGY



APPENDIX E: KABARAK UNIVERSITY VIRTUAL AREA NETWORK (VLAN)