
# A Framework of Wide Area Network (WAN) Optimization

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# DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the research project contains no material previously published or written by another person except where due reference is made in the thesis itself

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**Approval**

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# ABSTRACT

The fast increasing adoption of information technology and increased digitization has led to generation of large data which needs to be sent across the network. The world is becoming a small globe by the essence of networking and exchange of real information is paramount in many corporate agencies such as banks whose clients access their services throughout the country. Fast and consistent application response across the LAN and WAN help in ensuring uncompromised access to mission critical applications and services and enable high-performance businesses to use their applications to accelerate a competitive advantage.

This research covered how LAN and WAN optimization can be achieved through application of various existing technologies which are both on paper and practice. This was significant in establishing trends for emergent technology in this field of information and computer technology. LAN and WAN optimization ensures that the limited available resources are used effectively to ensure effective and efficient performance of the resources which are accessed through the network.

Owing to the increased exchange of data, security of the data from access by foreign or unauthorised individuals is fundamental, optimized WAN and LAN is inevitable. This is because, the data on transit passes through different networks, using different protocols, in various format which are vulnerable to security issues. Moreover, data loss as a result of corruption or crashing of existing data bases is one of the challenges facing corporate and thus data back up in a secondary site is important. Real time back up has been achieved as a result of effective WAN network between a primary site and a secondary site.

LAN and WAN optimization is therefore and important area of study to establish how security and back up can be enhanced. This further helps in reduction of both capital

expenditure as well as the running costs incurred by institutions on network management. The study achieved this through simulation of the various optimization technologies for LAN and WAN and measure the results from various case scenarios.

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May God Bless You All.

**Samuel Ribiro**


## DEDICATION

This study is dedicated to Calvin Ng'anga who ensured that he kept me on my toes by asking on the progress each time he would find me working on my laptop.

# LIST OF ACRONYMS

| | |
|---|---|
| LAN | Local Area Network |
| PC | Personal Computer |
| WAN | Wide Area Network |
| MAPI | Messaging Application Programming Interface |
| CIFS | Common Internets File Systems |
| TCP | Transmission Control Protocol |
| IP | Internet Protocol |
| UDP | User Datagram Protocol |
| FEC | Forward Error Correction |
| WAFS | Wide Area Files Service |
| WOC | WAN optimization Controller |
| OITS | Optimizing Internet traffic Services |
| GSLB | Global Server Load Balancing |
| URL | Universal Resource Locator |
| DNS | Domain Name Server |
| HTTP | Hypertext Terminal Protocol |
| API | Application Programming Interface |
| QoS | Quality of Service |

| | |
|---|---|
| SQL | Structured Query Language |
| DR | Disaster Recovery |
| RTO | Recovery Time Objective |
| RPO | Recovery Point Objective |
| ERP | Enterprise Resource Planning |
| CRM | Customer Relationship Management |
| SLA | Service level Agreement |
| IPSEC | IP Security |
| CIO | Chief Information Officer |
| SSL | Secure Sockets Layer |
| POP | Points of Presence |
| TFO | TCP Flow Optimization |

# CHAPTER 1 INTRODUCTION

## 1.1 Back Ground

The development of wide area networks (WAN) is traced back to services on point to point leased circuits that carried real regulatory weight and consequences for reliability to less reliable packet switch technologies with QoS but with substantially weaker SLAs and consequences for failure to meet the SLA. IPSec/SSL VPNs over broadband appropriately serves some data users however the broadband connections they used at remote offices were via providers and networks that have issues with network availability, frequently oversubscribed, and unpredictable performance latency, loss, and jitter. These networks were not reliable enough on their own for most business quality voice and mission critical data needs. The availability and the amount of bandwidth of broadband have continued expand while the cost per bit has continued to be lower. Network applications and users have continued to evolve to be more forgiving of smallest details quality service but are ever more demanding for more bandwidth. And they want their access to the internet and the cloud on their own terms with their own devices but on your constrained WAN budget.

The importance of Local Area Network (LAN) and Wide Area Network (WAN) to an organization includes; fast, access to applications and information. The management of LAN/WAN has been transformed to become simple in the recent with the emerging technologies Social and technological changes have drastically altered the nature of traffic and consequently increased the cost and performance issues for network managers and the institution as well. As traffic mushrooms, bandwidth costs escalate, application performance declines, and complaints multiply (Groth & Skandler, 2009).

There are numerous problems which are associated with the changing trends in technological field. This has even become more prone where there is consolidation of computing resources and applications accessed over the WAN. Moreover, the emerging technologies are dependent on the use of cloud computing as a platform for numerous enterprise applications. There is increased use of corporate communication which based on live and on-demand video and rich media that demand massive bandwidth. Moreover other recreational video sites and social applications which cannot be avoided by institutions are overwhelming the WAN. This calls for optimal use of these network resources to achieve better performance.

## 1.2 Problem statement

The development in information technology has brought about the need for exchange of large information on real time basis between offices which are separated by large distance. In lieu to these corporate have implemented virtualization of their data centers, and are concerned about data compliance and protection of their data. IT departments of most corporate bodies have therefore begun consolidating servers, storage and data from branch offices into central data centers (Cardwell, Savage & Anderson, 2000).

These strategies which are increasingly becoming the order of the day among most corporate have brought a number of significances to the institutions. The cost of management of both hardware and software has drastically reduced due to central access of information and application and also increases compliance in the use of information since it provides control for access and use of information of the institutions. However, this comes with a number of challenges such as increased demand on Bandwidth and hence leads to large number of performance issues (Machowinski, 2008).

Operations of some services such as CIFS; one of the legacy protocols for sharing Microsoft files and MAPI, one of the fundamental platforms for exchange, performance

poorly when they are accessed via WAN. Moreover, other protocols such as TCP also experience problems when transferring large data sets over WAN. Owing to the fact that data and other files as well as access of applications are carried out through WAN and LAN, there is a high buildup of demand for bandwidth hence network upgrades. The branch offices experience degraded application performance which leads to reduced productivity and reduced productivity.

These aspects call for optimization of WAN networks to improve on the performance and make its performance like that one of a LAN. This study endeavored to establish how optimization of LAN and WAN networks contribute to the performance of a corporate body. The study further explored the next generation technology that contributes to increased network performance (McQuerry, 2003 and Skorupa & Severine, 2010).

## 1.3 Objectives

The objectives of this study include;

i. To investigate emerging trend LAN/ WAN optimization technologies
ii. To investigate and simulate various network optimization techniques and case scenarios for various LAN/WAN networks
iii. Design
iv. Implementation
v. Testing

## 1.4 Research Question

i. What are the emerging trend LAN/ WAN optimization technologies
ii. What are the various network optimization techniques and case scenarios for LAN/WAN networks

## 1.5 Scope of the Study

The study is limited to corporate institutions in Kenya with several branches throughout the country; covering both WAN and LAN infrastructure. The study covers the optimization networks and its impacts on the performance of services that are carried out across the network as well as their implications on service delivery in the regional operational areas across the country.

## 1.6 Significance of the Study

The findings arising from this study informed the much needed analysis of the current state of LAN and WAN infrastructure in corporate bodies within the country. This provided a blue print of the mechanisms of network optimization as well as its impacts on performance. As the use of information technology is increasing by the day in most institutions, it is important to understand how to optimize the WAN and LAN networks where services are increasingly becoming dependent in offering ICT services. The impact of optimization of LAN and WAN on network security, capital expenditure as well as running costs were fundamental in this study. It is also important to undertake a study of the current level of optimization vis-à-vis the current technology and predict the future trends of network optimization.

The corporate bodies, through this research, develop an appropriate strategy and mechanisms for optimization of WAN and LAN network within and between their branches and consequently improve service delivery. The findings from this study will be useful not only to the corporate bodies to improve their services across the country but also the Kenyan government at large to enhance sharing of information and taking services to the citizens in support of the national E-Government strategy. The institutions of higher learning will use this study as a basis for further research, thus aligning their research to the current market demands.

# CHAPTER 2 : LITERATURE REVIEW

## 2.1 Introduction

Chris (1998) defines literature review as the selection of available documents both published and unpublished on the topic of interest, which contain information, ideas, data and evidence, written from a particular stand point to fulfill certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed.

## 2.2 Drivers of WAN Optimization

Previously, the LAN has been the core of a corporate network, with applications and systems hosted at the corporate headquarters, where majority of the employees accessing those resources were based. However, corporate are now focusing a large portion of their IT budget on procuring and extending WAN connectivity to reach the remote and mobile employee. Corporate WAN reliance, while driven by several factors has a many overarching benefits, including the changing physical nature of corporate and shifting philosophies on business processes.

### 2.2.1 Connectivity in a Disconnected World

In the past, corporate were generally centralized organizations with the majority of employees, applications and activities taking place in a single geographic area. Branch and remote offices still existed, but they were secondary to the headquarters. Now major business operations are increasingly moving to remote and branch locations and employees are becoming mobile or remote. Corporate are also facing greater mobility among their employees, especially with the widespread acceptance of portable devices and remote accessibility. Corporate have to be certain that the productivity levels of these out-of-office employees are not being adversely affected due to a lack of resource delivery and access. So

while corporate are becoming physically more dispersed, they simultaneously need to be more connected. This need to stay connected in a disconnected environment is a principal factor driving WAN dependency by corporate as all the mobile and remote workers access the centrally located resources through the WAN.

### 2.2.2 Globalization

It's now a common practice for corporate to establish branch offices all over the globe in order to take their services closer to their clients. This practice however comes with a cost of moving massive amount of data over the internet network. This trend is due to globalization, a factor driving growth among corporate WAN services, and it is increasingly becoming a priority to keep geographically disconnected offices connected through a reliable WAN network. Global offices require the same access to the resources and applications that the headquarters and domestic branch offices host centrally, but they face the additional challenge of extreme distance and inconsistent local connectivity, especially with public internet services. Global connectivity is becoming a principal pain point for large multinational businesses all over the world and this has placed a challenge to the CIO's globally.

### 2.2.3 Data Backup and Disaster Recovery

A Corporate ability to back up data in all remote locations and to transition seamlessly from one data center to another data center is very crucial and more so over constrained bandwidth recourses. However, these operations, which require moving massive amounts of data across a WAN network in real time, often come at a high cost and a level of inconvenience due to constrained WAN resources. Corporate are seeking alternatives to traditional WAN data-backup services to minimize the cost and disruption of data-backup activities as mitigation to Disaster Recovery which is very critical for business continuation management during a disaster. This has necessitated the need of corporate deploying data

centers at various geographical regions to ease massive data movement over the constrained resources.

### 2.2.4 Desktop Virtualization

CIO's are now adopting the VDI technology in order to drastically cut on their budget. This has led to the CIO's facing the challenges for corporate-IT management with distributed locations with the issue of desktop management. Desktop virtualization can reduce operational challenges associated with remote PC management, but it is often restricted by poor network connectivity, varying availability, and bandwidth resulting to poor end user experience and hence the need for WAN optimization because of the massive amount of data movement in the WAN.

### 2.2.5 ERP and CRM applications

Mission-critical corporate applications like resource planning (ERP) and customer relationship management (CRM) applications suffer in performance when accessed over a WAN due to bandwidth issues over big distances. A systems responsiveness is often far worse for remote users than for a user at headquarters, which results in productivity loss, opportunity loss, and revenue loss. This makes the end user to have a very poor user experience and most of the times not meeting the target as expected. WAN optimization has come in handy to improve the performance of the mission critical applications and therefore improving the performance of the end user.

### 2.2.6 Real-time Communications

Real-time applications, particularly voice and video, have strict requirements on transport delay, jitter, and packet loss that place significant pressure on bandwidth availability. Such services are driving the demand for traffic-prioritization (QoS) strategies that will minimize congestion risk and deliver high-quality voice or video. QoS is a crucial WAN optimization technique as it enables a corporate to prioritize its traffic so that mission

critical applications are given first priority. This helps the corporate to meet their business objectives and at the same time keeping their customer base.

### 2.2.7 Server Virtualization

Server virtualization allows enterprises to enable applications from a co-location facility, which effectively reduces OPEX and CAPEX while improving security. However, for server virtualization to be effective, WAN connectivity must support reliable and timely access to those applications from physically remote locations. This practise introduces huge traffic in the WAN and hence the need for an effective WAN optimization.

## 2.3 Emerging Trends in LAN/WAN Optimization

Network is a crucial component of any given corporate in the modern society particularly in enhancement of application performance. Most crucial business applications are hosted by corporate bodies are conducted in an integrated network environment. Most service providers in collaboration with manufacturers such as Cisco have invested heavily in research and development in building integrated WAN and application optimization solutions to support a broad set of applications with different requirements, from IP communications to transaction-oriented applications. There is increase in advancement in the technologies used for optimization of LAN and WAN resources across the globe (Forouzan, 2007).

Network and application performance is greatly affected by security concerns. A complete, holistic solution delivers more than comprehensive WAN and application optimization capabilities, but also cooperates with security components to protect business against disruption. One of the widely used optimizations approaches is a network-based, end-to-end systems approach that evolves with business needs and enables the opportunities generated from future technical innovations (Mun & Ramjee, 2008).

Optimization of WAN is implemented in line with the applications which are to be accessed through the network resources. This involves an architectural solution made up of a

set of tools and techniques working together to improve the reliability, performance, and delivery of applications securely across the corporate network. A strategic systems approach uses the network to identify applications running in the network, gains end-to-end visibility, optimizes the network and applications, and controls and protects business critical traffic (Rolfe, 2006).

WAN and application optimization solution consists of five critical components for effective application delivery. The major components of such a system include classification, control, optimization, network management and monitoring.

The traditional WAN optimization provided a significant value in an environment where the applications and data the users are accessing are in a fixed location and under the control of the enterprise. However, a new set of optimized WAN services is emerging which is highly complementary to the traditional approach to WAN optimization. This emerging set of solutions is focused on environments in which corporate are in control and others not in control and hence the need for adopting the new emerging WAN optimization techniques. These emerging WAN optimization trends are covering both the environments that the corporate are in control and the ones that they are not in control; an example of an environment where the corporate has no control is where a mobile user is accessing applications and data from a cloud provider. There is no doubt that ensuring acceptable levels of user experience in accessing the applications and service delivery is a challenge in the emerging environment than it is in the traditional environment. This then leaves the corporate with no choice but to embrace the emerging trends in WAN optimization for their optimal service delivery.

These are some of the emerging trends in WAN Optimization.

### 2.3.1 Emergence of mobile users

Corporate users are increasingly accessing business critical applications on mobile devices, including smart phones, laptops and tablets, from a variety of locations, while

expecting optimal quality of user experience. However, traditional WAN optimization solutions were not designed to support these types of users. WAN Optimization spectrum shows that software solutions for optimizing application delivery to mobile devices are the number one technology capability that organizations are looking to deploy. Currently, only a few vendors are able to provide this type of capability. As these trends progress, it is becoming increasingly difficult to determine the "edge" of the WAN, the spot where the company's conceptual framework ends and other vendors or users begin. A Wide Area Network, which previously may have only encompassed the company's physical locations, can now be thought of as including mobile users, cloud providers and potentially anyone else the WAN optimization needs to extend to. The definition of a Wide Area Network is changing and organizations are increasingly finding that traditional approaches for WAN optimization are becoming less effective and hence the need to adopt the emerging WAN technology trends in order to house and meet different needs of its users with acceptable user experience and optimal system performance.

### 2.3.2 Cloud based, private WAN optimization

With the emergence of cloud computing, there is need to improve the performance of applications just like in a traditional WAN setup. A cloud based, private WAN optimization services a variety of types of users, for example mobile users, branch office users access WAN optimization functionality at the service providers points of presence (POPS) and the POPS are interconnected by a private WAN. This includes WAN services such as Virtual Private Networks (VPN) and Multiprotocol label switching (MPLS). A solution of this type supports a wide variety of access services. This type of solution must have enough POPS so that there is a POP in close proximity to the users and to the applications and the data the users want to access so as to not introduce unacceptable levels of delay in service provision in the spectrum of the corporate.

### 2.3.3 Optimization of Internet Traffic

The traditional WAN Optimization Controllers (WOC) were designed to address application performance issues at both the client and the server endpoints but with advancement in technology, this setup is no longer meeting the need and hence the need to adopt technologies that will offer a holistic solution to the corporate. The traditional solution made the assumptions that the performance characteristics within the WAN are not capable of being optimized because they are determined by the relatively static service parameters controlled by the WAN service provider. This assumption is reasonable in the case of private WAN services such as MPLS. However, this assumption does not apply to enterprise application traffic that transits the internet because there are significant opportunities to optimize performance within the internet itself. This WAN optimization service focusing on internet traffic is referred to as an Optimizing Internet Traffic service (OITS). An OITS leverages service provider resources that are distributed throughout the internet. All the clients' requests to the application's origin server in the data centre are redirected via DNS to a server in a nearby point of presence (PoP) that is part of the OITS. This edge server then optimizes the traffic flow to the OITs server closest to the data centre's origin server.

The servers at the OITS provider's PoPs perform a variety of optimization functions. Intelligence within the OITS servers can also be leveraged to provide extensive network monitoring, configuration control and service level agreements (SLA) monitoring of a subscriber's application and can also be leveraged to provide security functionality.

Some of the optimization functionality provided by an OITS is similar to the functionality provided by the traditional WOC. This includes the optimizing the performance of protocols such as TCP and HTTP. Some of the unique optimization functionality that can be provided by an OITS included choosing the optimal path through the internet, offloading data out of data centres to caches in OITS servers close to the users, and increasing availability by leveraging dynamic route optimization technology.

### 2.3.4 Hybrid WAN Optimization Solutions

**Load Balancing (Global Server Load Balancing)**

Load balancing is a technique that is used for distributing the workload evenly across computing environment. The Global server load balancing (GLSB) has various configuration models.

Ideally GSLB goes through the following,

1. User requests received are redirected to other closer sites Data Canters (DC) in case the usual DC or server does not respond.
2. Forwarding the visitor requests to the site that is closer to the place from where the request is raised from a geographic point of view.
3. In case a threshold is reached at a site, the requests are forwarded to other sites which may be at a different geo-location; the algorithm would calculate the shortest distance from when the request has been raised.

## Scenarios and Requirements:

In this load balancing technology (GSLB), services or websites are hosted on different servers located at different geo-locations. Let's consider, a visitor is browsing www.olx.com from Kenya, in usual web hosting, this request would be sent straight to the server where it is hosted, and the request would be served from the UK server only where the web is hosted. On the contrary, the Global Load Balancing architecture, the website is hosted on servers across different servers located in different geo-locations, the user trying to access the website from Kenya, would be served from the server that is located in Kenya. The GSLB in a regular time interval checks the health of the slave servers for providing the best response hence directing the traffic to those servers.

There are generally two methods on how GSLB can be configured:

1. GLB – Global Load Balancing
2. . DNS Load Balancing

1. GLB – Global Load Balancing:

In this technique of GLB, the use of a primary server also known as the Master Server and is connected to Slave Servers located in different geo-locations that is in different DC's. Whenever a request is raised, the Master Server checks the location from where it was initiated. Then cookies are set and it redirects the request to the nearest server location.

Process Flow:

i. The user (in this case user is in Kenya) types the website url http://www.olx.com in the browser. Since global load balancing is applied, the request would first go to the Master server which is located in UK data centre.
ii. The Master Server would send a query to the requester for querying IP address, upon confirmation of the users IP address; cookies are set which contains every information on the user system.
iii. This information is forwarded to the Master Server which is in the meantime checking the health and level of responsiveness of the slave servers.
iv. Now the Master Server in the GSLB architecture would redirect the request to nearest Slave Server (i.e. in Kenya).
v. The users get a response and are able to view the website which is served from the Kenya server and not the UK servers.

All these processes happen in fraction of seconds without the knowledge of the users.

A constant synchronization takes place between Master and Slave servers across all the DC's.

2. Global DNS Load Balance:

Load Balancing can be achieved using DNS technology. In this the response to the DNS requests depends on requester's geographic IP location and the response from DNS.

Considering a similar example as above: If a user requests for http://www.olx.com, it is sent to GSLB DNS Server which would check the IP of the visitor. Then it would identify the

server that is closest to the location or to the one that has the minimum response time, and the traffic is forwarded or redirected accordingly

Process Flow:

i. The user based in Malaysia tries to access the site wwwolx.com. In this case the DNS Request is sent to the ISP and further to the GSLB DNS Server.

ii. Then, the GSLB DNS Server forwards the request to Name Servers of all the Countries or to the GSLB Server located in various geo-locations.

iii. Within fraction of second, the GSLB receives the response from every server, it then analyses the response time and identifies the Closest Server Location from the Users Request and then redirects it to that server.

iv. The users in this way get connected to the closest server. In this scenario, the user request is initiated from Malaysia; hence the closest server as identified by GSLB serves the request to the requestor.

## 2.4 Emergence of New Deployment Methods

Study shows that while physical appliances are still the most predominant method for deploying WAN optimization solutions, other methods of implementation, including software and Cloud services, are showing strong growth rates very fast. Research shows that corporate who are deploying WAN optimization are still not optimizing 54% of their remote locations. This comes as a result of challenges associated with deploying physical appliances and the inability to cost justifies these technology purchases. The innovations in the WAN optimization space and new deployment methods have created a number of new use cases for deploying these solutions and expanded an addressable market for these vendors.

Corporate are reporting that some of the key reasons they are deploying (or replacing) WAN solutions are deployments of technologies such as video, mobility, virtualization and Cloud. Additionally, organizations are increasingly finding WAN optimization technologies effective when dealing with emerging IT management challenges, such as Big Data. The

value of these technologies and IT projects heavily relies on network performance and the quality of user experience. For that reason, organizations are seeing WAN optimization capabilities as integral elements when ensuring that they get the most out of the investments that they are making in modernizing their IT infrastructure and bringing their IT services closer to end-users.

These emerging trends are significantly impacting how WAN optimization solutions are being evaluated and deployed. Additionally they are changing the role that WAN optimization technologies play in end-user organizations. The addressable market for WAN optimization solutions is increasing, and the impact of these solutions are spreading across different areas of IT and business and benefiting more users. In addition, WAN optimization has been elevated to a more strategic level in the CIO's viewpoint. What was once seen mostly as a cost-saving measure now has real strategic impact on the entire organization and addresses some of the key items on CIOs' agendas. In order to take advantage of this opportunity, WAN optimization vendors need to prove that they are willing to venture out of their comfort zones, innovate and build capabilities for effectively addressing new use cases for WAN optimization.

### 2.4.1 Next-Generation WAN Optimization

The new developments of the WAN design and deployments means WAN optimization needs to evolve. Currently, WAN optimization has been a tactical technology, mainly acceleration, used to speed up the performance of real and non-real-time applications -- such as e-mail and Windows file services over private WANs. As earlier stated, the private WAN is becoming a thing of the past as corporate networks are extending well past the firewall. Additionally, the variety of application types has evolved. Multiple application types require more than just one acceleration technology and drive the need for a broader array of WAN optimization techniques.

WAN optimization means anything that sits at the WAN edge and optimizes network performance. The evolution of WAN optimization actually moves us closer to this definition than acceleration technology has. However, the technologies that make this up are quite varied and are used for different applications.

Next-generation WAN optimization needs to include: network visibility tools that show what's running on the network; security functionality to secure traffic over the networks; and Technologies that improve the performance of all applications, including video, static content, cloud applications, Web applications and other non-real-time or real-time applications.

This will move WAN optimization from being a tactical technology used to solve a few application performance problems to a strategic technology that will solve the majority of today's application performance problems and stay in step with the demands of a next-generation WAN.

### 2.4.2 LAN/WAN Optimization Techniques

There are several techniques which have been used in optimization of WAN and applications being accessed across the network. These techniques on application to network traffic, they dramatically improve application performance and availability, reliability, decrease latency as well as improving bandwidth utilization, and bolstering security (Kurose, & K. Ross, 2005).

TCP Flow Optimization is one of the enhancements of WAN that improves the TCP stack and brings uniformity to TCP sessions. This technique mitigates the inherent lack of performance in TCP slow start and general flow control, causing reduction in the speeds with which data is transferred across the network. TFO techniques fill the pipe and reduce latency, resulting in faster transfers and optimal bandwidth use.

WAN optimization can also be achieved through advanced compression the leads to redundancy elimination (DRE); a technology that replaces matching byte streams with a

signature, consequently reducing the amount of data sent through WAN. Signatures can be defined as libraries which are maintained on opposite sides of the peering devices and enable compression ratios of up to 100:1. Further, another technology known as standard (LZ) compression is fundamental in compresses non-redundant data for maximum compression levels.

Another commonly used WAN optimization technology is Path Optimization. This technology is dependent on the number of possible paths that a given service centrally placed or placed at different locations in the WAN can be accessed. The technology uses intelligent end devices which aid in identification of the best paths for accessing applications and data at any given time to the hosts as required. This technology ensures that there is no congestion within the network. This ensures that data and applications are available and easily accessible by the hosts on the network (RIVERBED, 2006).

Load balancing is also a technique which has been widely used to reduce the work loads of services which are accessed by large number of hosts at a given time. This is applied in cases where there are a number of servers which provide the same services located in the same location or different locations. The load balancers are intelligent equipment which balances access of services between two or more servers, consequently reducing the loads on a particular server. The same technology of WAN optimization can be achieved through the use of connection management and offloading Secure Socket Layer (SSL).

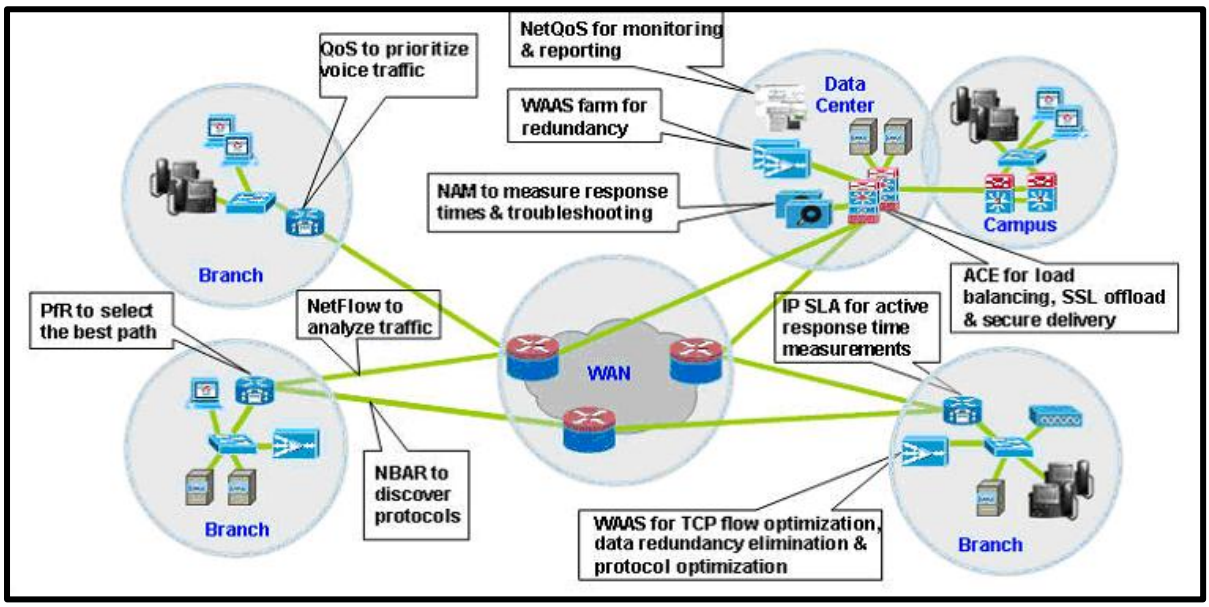
Implementation of secure WAN environments can be viewed as an optimization technology because it reduces the possibilities of threats which might interfere with access of WAN resources. This is achieved through the use of Firewalls, SSL encryption and intrusion prevention systems which prevent or minimize denial of service and other threats that protect applications and critical business information assets. The use of secure VPN technologies promotes low-latency paths by enabling direct spoke–to-spoke communications. DNS

Optimization also help in accelerating Domain Name Servers lookups helps to ensure speedy application delivery (Forouzan, 2007). .

Enterprise Content Delivery Network (ECDN) technology is significant in improving reliability and performance of content and application that are delivered across the WAN. ECDN typically is made up of comprises policy-based distribution, caching, redirection and content management. Together, these components enable enterprises to efficiently distribute content to its remote branch offices (Rolfe, 2006).

### 2.4.3 LAN-WAN Optimization Process

The initial stages of LAN-WAN optimization are mainly concentrated on the data centre and core switches and the main branches. The process expands to touch on various areas in the network. The most common approach used in LAN-WAN optimization is the one that looks at a network as a platform used to identify applications on the network, gains end-to-end visibility, optimizes applications, and controls and protects business-critical traffic (JR, 2007).




## 2.5 Importance of Optimizations

WAN optimization has enabled customers to put off impending bandwidth upgrades for two years or more in some cases. In addition, some companies have been able to

decommission existing circuits because of throughput gains. Customers have also been able to avoid router upgrades, enable greater consolidation, and avoid server refreshes. This frees up budget for the bottom line and for other critical projects. WAN optimization acts like a multiplier to the investments you are making in other projects. Initiatives as diverse as CRM, ERP, disaster recovery, communications platforms, and more benefit from greater performance and less need for distributed IT infrastructure. WAN optimization makes these new projects perform better over the WAN, accelerate user adoption, and costs less to implement (RIVERBED, 2006).

WAN Optimization has also enabled virtualization which is often considered a key cost-savings strategy, but one critical area is often overlooked. If you're consolidating servers out of a branch office and virtualizing them into the data centre, end-user performance problems could kill your project. WAN optimization enables LAN-like performance over the WAN, allowing branch users to still have the required application performance. Optimization of WAN also enables balancing of workload without reallocation of resources. Typically big projects rely on staff at the project location, but leverage some to little staff elsewhere. But with WAN optimization, much of the work can be done remotely, where the staffs is located today. Even challenging design tasks requiring significant collaboration can be handled remotely. This eliminates significant cost in travel such as flights, hotels, and transport. In addition, all of this travel time is freed up for staff to actually work on the project without tearing them away from their personal lives.

Optimized network is always fast and boost the morale of the users of the network. In down economies, employees still want to work hard but application performance often seems like a barrier to them. This can cause workers to be less productive and therefore less satisfied with their jobs. By using WAN optimization to accelerate the performance of applications, IT managers can eliminate a key barrier to enabling productive, happy workers. Acceleration of performance of applications over WAN reduces the costs of support for the

network by a significant margin. Mobility is often considered a way to make employees more productive and get them closer to the customer. But it can also be a cost-savings strategy. Using WAN optimization software for mobile users allows them to be connected to the enterprise as if they were working in an office. With that level of performance, users can work from the home more frequently and reduce the burden on companies in terms of branch office operating costs and real estate investments.

Further, optimization allows an institution to engage in productive outsourcing activities which leads to securing technical resources. Outsourcing only really works when the remote staff can access information and data as if they were local. With WAN optimization, organizations can enable just that. In addition, they won't get stuck with requirements to buy large, expensive international links or set up remote infrastructure on the outsourcers' premises. Optimization also helps in data protection at all times. Many businesses simply throw more bandwidth at data protection in the hopes that they can replicate and restore an ever increasing amount of data in an ever-shrinking backup window. Organizations that use WAN optimization often see that they can accelerate their disaster recovery operations while cutting bandwidth needs at the same time.

WAN optimization also allows organizations to cut costs without sacrificing the future. Because WAN optimization is an enabling technology across the complete enterprise, a small investment now can prepare the business to grow rapidly when the time is right. New IT projects can be deployed faster and with better performance across the WAN. This enables the IT department to be more responsive to business needs in good times or bad (Kurose, & K. Ross, 2005).

## 2.6 The Future of Network Optimization

Delivery of mission-critical supplies to remote or hazardous areas, ensuring full mission operability, even when distribution networks are disrupted. Today, many

organizations face these or equally daunting challenges while simultaneously balancing mission demands for improved performance against tighter budgets. New technology, better information systems, and faster, worldwide communications can contribute to a solution, but failure to address the underlying structure of an organization's supply distribution network too often results in disappointment. Meeting customer demands for top performance means redesigning supply distribution networks to meet current and future missions.

The ever increasing data and increased devices which operate in a given network are drastically increasing. While there is congestion, there is increased demand for fast networks and more data is being injected into internet sites. It is also imperative that there is increase in the generation of information which is send across the network. It is always costly to keep on increasing the amount of Bandwidth to gather for the increase in the amount of data being sent across network (JR, 2007).

The solution for this predicament lies in the use of optimized networks. Optimization is aimed at reducing the amount of time taken by information and applications to be accessed across a wide area network. The future of these technologies presents a myriad of solutions to this predicament facing network utilization. The first solution to these will be implementation of intelligent filters. This are equipment that are strategically placed so that it can select and prioritize some certain data and application ensuring that they are accessed easily by its users over the LAN. These data and application being prioritized are of great significance in improving the speed of access of information and applications which form the core mandate of an organization.

Another method of optimization technologies reduces the amount of data to be send across a network and consequently makes its access to be faster and at the same time accumulate large amounts of data. This technology compresses the amount of data before sending it, the data will be decompressed upon reaching its destination. Further companies

are using private clouds to share information over WANS. Private clouds are faster since they are isolated from any other internet information which may not be necessary.

The future of WAN optimization will see introduction of WAN optimizers both in the data center and at every point in the network where there is data interchange such as at branch offices and core switches and routers. The introduction of optimizers will ensure that Networks are safe and information is accessed faster and with the use of limited bandwidth (Mun & Ramjee, 2008).

## 2.7 Conceptual Framework

The conceptual framework which guides the study is as shown in figure 2.1 below.

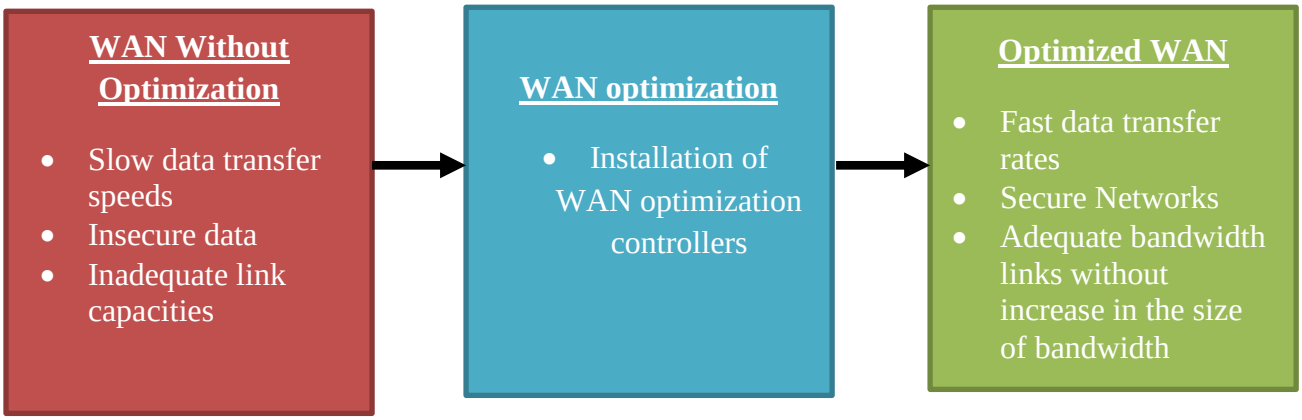



***Figure 2.1: Conceptual Framework***

# CHAPTER 3 : RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter entails a discussion of the methods of research that was instrumental in this project and qualifies its selection over the other possible designs. It begins by addressing, in detail, the project design to be employed. Further it explores the procedures employed and data collection techniques that were fundamental in this study. A recap of the chapter is provided at the end.

## 3.2 Research Design

This is an experimental study which is fundamental in analysing characteristics of a given phenomenon that can be modelled or experimented (Cooper and Schindler, 2003). Cooper and Schindler (2003) argue that, experimental analysis helps in discovery and measurement of various attributes of various parameters of a given model which represents a real life case scenario. Saunders, Lewis and Thornbill (1997), believes that experimental studies paints a clear picture of phenomena under study while Robson (2002) points out that the main concern of experimental study is to depict accurate profile of case scenarios. In this study, the focus is on the optimization of LAN/WAN networks in a corporate agency.

According to Sekaran (2003), Experimental studies are undertaken when the parameters of phenomena to be tapped in a situation are known to exist and one wants to be able to measure and simulate various cases while taking measurements. This was important in collecting in-depth data about the case under study. The advantage of this design is that it helps in establishing the features of optimization of drastically increasing use of WAN/LAN in Corporate institution in Kenya. This study approach aided in identification of the most applicable frameworks that can be used as a platform for optimization of networks.

## 3.3 Data Collection Methods

Primary data collection methods were used in this project. The data was ascertained using simulated computer networks and using different tools, a real case scenario is going to be simulated. Once the case is simulated, various cases were simulated and measurements made.

### 3.3.1 Research Procedures

Transmission Control Protocol (TCP) was developed as a local area network (LAN) protocol with the advancement of the Internet which was expanded to be used over the WAN. Over time TCP has been enhanced, but even with these enhancements TCP is still not well-suited for WAN use for many applications. The primary factors that directly impact TCP's ability to be optimized over the WAN are latency, packet loss, and the amount of bandwidth to be utilized. It is these factors on which this optimization solution focuses on. This study used WAN optimization controllers which are installed within the network.

The network topology shown in figure 3.1 below was simulated in GNS 3 software and the speeds for different amount of data was injected into the network using traffic generators and the speeds of the data transmission was recorded. This process was repeated for the case where there are WAN optimization Controllers (WOC) and in the case where there are no (WOC). The results were then graphically presented for both cases. A comparison was made for the various case scenarios forming basis for discussion.

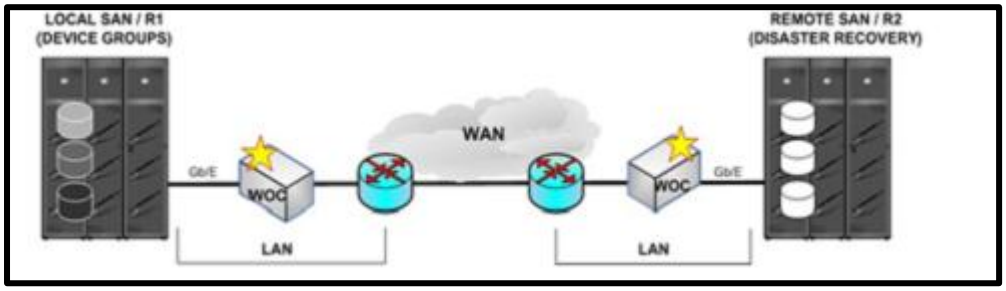


*Figure 3.1 optimization Model*

## 3.4 Chapter Summary

This chapter is a description of the methodology to be used in carrying out this project. Experimental research design which focused on optimization of LAN/WAN Simulation of a corporate agencies. Primary data collection techniques were used in collection of data for this study. The chapter has also indicated how data was analysed and represented. The project formed the basis for development of a framework for the various LAN/WAN optimization options. The next chapter presents the findings of the research and the discussion

# CHAPTER 4 RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter gives the results from the simulations of WAN that captured various operational parameters of the network. The results are in two steps; the first one is where there are no WAN optimizers while the second one is where there are network optimizers. This aimed at ascertaining the operational difference between optimized network and non-optimized case.

## 4.2 Results

Results give a comparison between various parameters of simulated WAN network. The measured parameters include packets sent within a given time and the number of packets received within the same time. This was compared across the optimized and non-optimized networks.

### 4.2.1 Packets Received and Sent

The amount of packets received at a given node. The results were collected over a period of 30 seconds and recorded for both optimized and non-optimized network. The amount of packets sent through a given network within a given time of similar bandwidth is an indicator of how efficient that network is in terms of access to services. The measurements were measured between WAN networks gathering data from all VLANS and all ports. The results were plotted on a graph to indicate the difference between the two networks as shown in figure 4.1a and 4.1 b below. From figure 4.1 a, it can be seen that the amount of data received within a given time is higher for optimized networks. The data points represent the amount of data received in 30 seconds. It can be seen that the amount of data is higher for all the instances by approximately 60 kbs.

This is an indication that in an optimized network the passage through which the data is transmitted has smaller resistance and appears to be wider and exhibit minimal resistance. In figure 4.1b, the data received from an optimized network is also higher as compared to that of non-optimized network. However, the difference is not as much as it is for the case of received packets. This could be attributed to the fact that sending and receiving of data by a computer uses different ports and protocols. Optimization of WAN increases the performance and ensures that sending and receiving of data is achieved efficiently. When the data received and sent is high, it indicates that a large number of activities can be done across the WAN when it is optimized. This shows that there is high efficiency and performance.

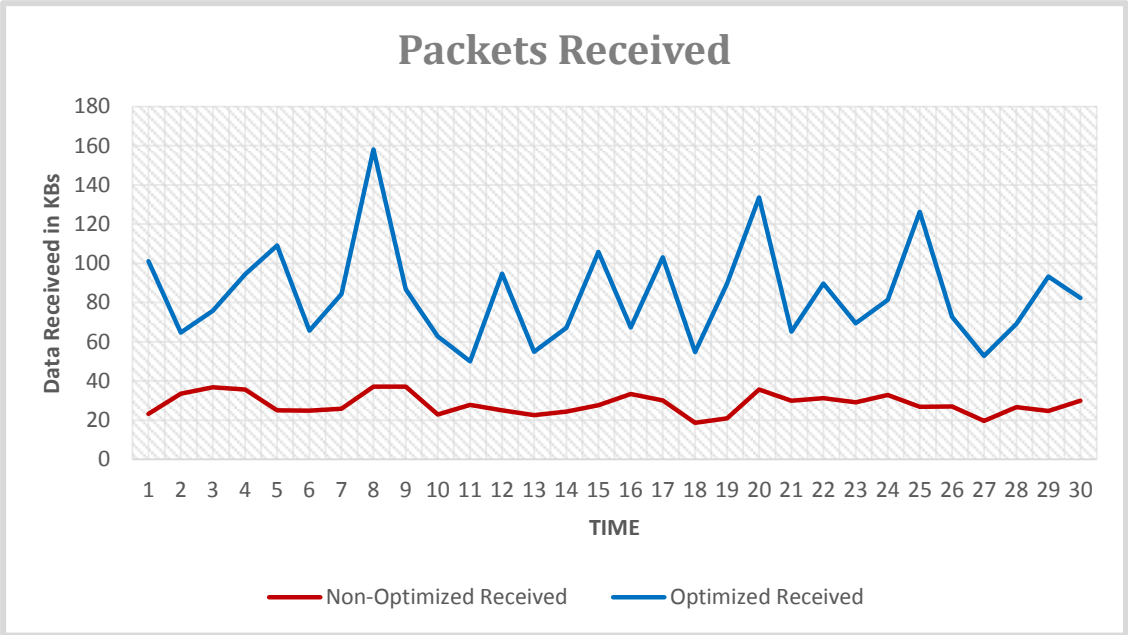



***Figure 4.1a: Graph of Data Received for both Optimized and Nor-optimized WAN***

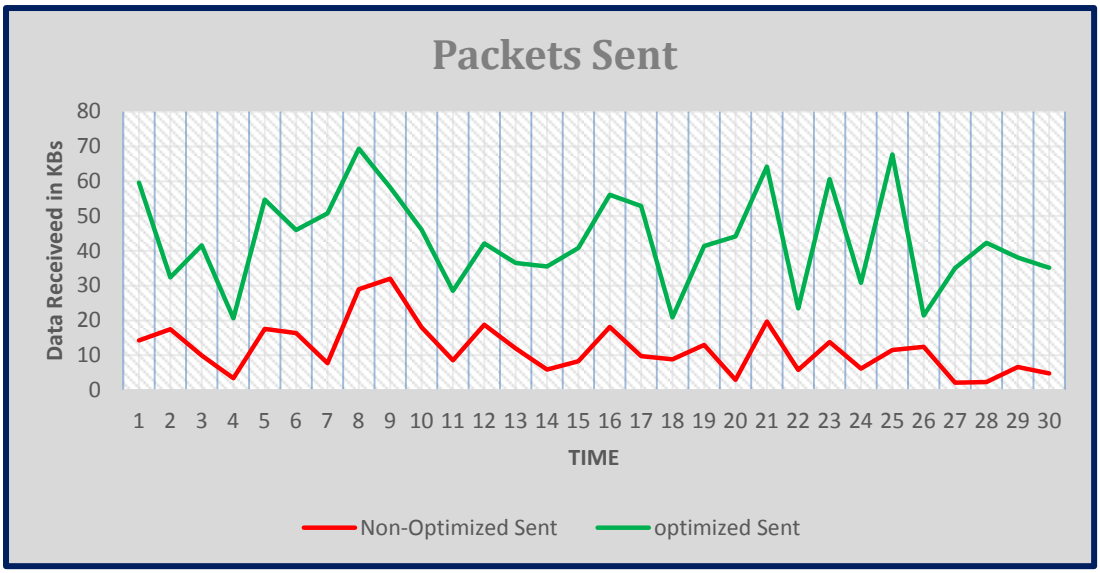



***Figure 4.1a: Graph of Data Sent for both Optimized and Nor-optimized WAN***

### 4.2.2 Packets dropped

The number of data packets dropped is an indicator of the amount of data packets that delayed beyond the set threshold and consequently they are dropped. A large number of data packets are dropped in the case where the network is slow but when the network is optimized it becomes faster and data sending and receiving experiences less delay and that way very few packets are dropped. In figure 4.2 below, it can be observed that there is a large number of data packets dropped in the case of a non-optimized network. Further, it can be noted that the number of packets dropped is low and fairly constant for an optimized network. Optimization improves on network latency and increases the network efficiency in the sense that there is very little data packets dropped while sending and receiving a large volume of data.

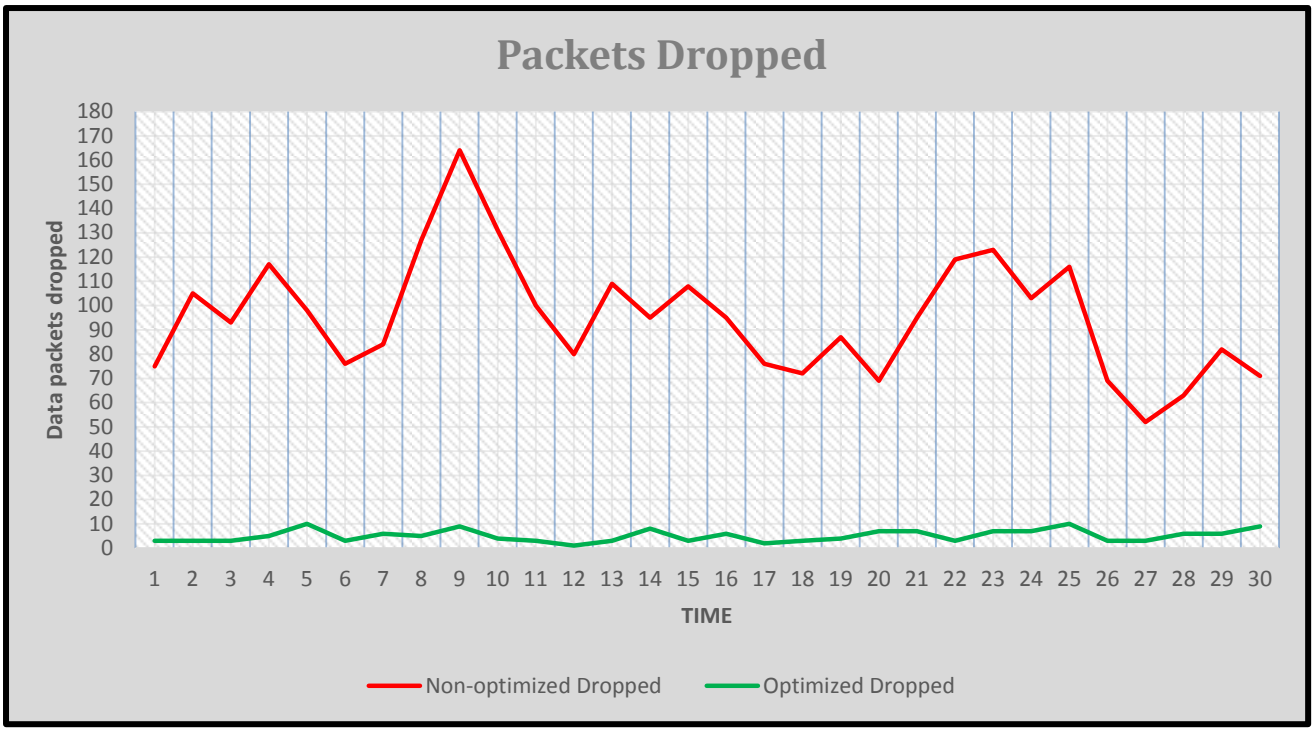



***Figure 4.2: Graph of Packets Dropped for both Optimized and Nor-optimized WAN***

## 4.3 Discussion

In the modern world where there is massive data to be transferred across WAN to enable an organization to complete their business processes. Most organizations have their systems located at a strategic location either locally or off shore. The implication of this is that all transactions are carried out across the WAN. In the occasions where transactions are conducted within a branch office, regular data back-up is done to a remote site over the WAN. This involves sending and receiving of data from either of the nodes. The techniques which are deployed in optimization of WAN to maximize the amount of data sent and received within a given time and at the same time minimizing the amount of data packets dropped in the process.

The data received and sent as well as those dropped are noticed by the end user without understanding of the technology behind it. In this discussion some of the technologies are

discussed. These include de-duplication, Optimization compression, wide area file service, WAN optimization forward error correction and web caching.

### 4.3.1 WAN De-Duplication

This is the process of removal or elimination of any redundant data to be sent or stored within the WAN. This not only reduces the storage space but also reduces on bandwidth utilization. This is also referred to as capacity optimization or intelligent compression that ensures that there is single instance storage. The process of de-duplication involves maintenance of a single copy of each document is stored and accessed by all the users from the various parts of the network. During this process, data indexing is maintained across the board and ensures that the data can be accessed easily should there be a need to access the data. The methods of data de-duplication have a significant impact on the efficiency of network, especially on bandwidth utilization.

There is a number of significance that ensure from data de-duplication. These include enhancement of data protection, acceleration of speed and sustainability of bandwidth and storage costs. Organizations that have implemented data de-duplication techniques have significantly increased on the integrity of its data as well as significantly reducing the cost of data protection systems. Data de-duplication is paramount in virtualization because it is used in transformation of data centers through de-duplication of VMDK files and snapshot files

De-duplication aides in reduction of the cost of storage as only a fewer disks will be needed for storage. By employing this technique, there will be much lesser data to transfer over the WAN for purposes of replication, disaster recovery, and remote backups. This results in shortening of backup and recovery time. Longer Recovery Time Objective (RTO) is achieved through the optimal use of disk space, which allows longer disk retention periods. It also substantially brings down the necessity for tape backups.

Types of WAN De-duplication

The main aim of deployment of de-duplication techniques includes improvement of bandwidth efficiency as well as storage requirements. The different categories of de-duplication methods include: Data de-duplication, File de-duplication, and Block and Bit de-duplication. Data de-duplication is the most preferred and commonly used productive method. This method is commonly used on the file, block, and also the bit level. File de-duplication is used for eliminating duplicate files, however, it is not considered to be a very efficient de-duplication method. In the Block and Bit de-duplication method, the contents of the file are analyzed and the unique iterations of each bit or block are saved. Hash algorithm is used to process each data chunk. Only when a file is update, the changed data will be saved. Block and Bit de-duplication requires much processing power and a large index to enable tracking individual elements.

Identification of duplicate data segments, the data de-duplication process is dependent of cryptographic functionalities. The disadvantage of this method is that if a collision happens, the result would be loss of data. Technology vendors have developed various solutions to address this problem. Data de-duplication has become a leading technology process and many vendors including Virtual Tape Library (VTL) vendors are placing it on demand.

### 4.3.2 WAN Optimization Compression

This is an optimization technique which involves reduction in the size of the data to be sent through the network. This saves on the time that the data is sent across the network and also the space used for storing the data.

### 4.3.3 Wide Area File Services (WAFS)

Organizations whose services are network-driven are increasingly optimizing their services and networks for accelerated and optimized performance. Business continuity is a significant component of today's widespread business scenario, which requires advanced technology for redundant and continuous efficient performance. It is the desire of any organization to gain maximal use of their network infrastructure through deployment of various optimization technologies.

One of the technologies which has been used in Wide Area Network Optimization is WAFS which is a storage technology, which enables accessing a remote data center possible over a WAN like it was a local connection. This is achieved through WAN optimization and application acceleration. Network or WAN congestion and disruptions can be decreased by large margins by caching. WAFS is capable of caching Secure Sockets Layer (SSL) Intranet, multimedia traffic, and ASP applications. It also accelerates WAN traffic thereby building a sound network. WAFS make use of techniques such as data compression, Messaging Application Programming Interface (MAPI) protocol optimization, Common Internet File System (CIFS) and at times storing repeating data patterns in a local cache.

Business organizations having remote office/branch locations can access and share resources/files globally across the Wide Area Networks by using Wide Area File Services products. A distinguished feature is that WAFS enables data sharing at the Local Area Network (LAN) speeds. WAFS solutions are executed through the use of distributed enterprises that consolidate data storage in corporate datacenters, which eradicates the necessity for backups and managing data earlier stored in data at remote centers.

Given the unique characteristics of Wide Area File Services, academic institutions, businesses, organizations and governmental agencies with many branch offices which are

networked, are able to manage data backups from a centralized location in real time. Data backup on servers at different physical locations enhances security. WAFS systems normally constitute Edge File Gateway (EFG) appliances and one or more Central Server (CS) appliances. The EFG appliances placed at remote office locations access storage resources with the aid of CS appliances. The benefits of deployment of Wide Area File Service data archiving, continuous read/write access of data, LAN like speed in data transfer, low latency, quick system recovery, Compression and increase in speed and advanced data security.

# CHAPTER 5 CONCLUSION AND RECOMENDATION

## 5.1 5.1 Introduction

This chapter covers the discussion of the results achieved from the previous chapter. The discussion first looks at WAN optimization techniques and discusses the results vis-à-vis other results gained from literature review. The conclusion forms a major part of this chapter. The conclusion gives way to recommendations from the findings of this research and the experience involved throughout the process this project.

## 5.2 Conclusion

The conclusion of the study covers three main areas; results from the simulation, emerging WAN optimization trends and various case scenarios for application of these technologies.

### 5.2.1 Emerging WAN Optimization Trends

The study has shown that there is increased dependence on sharing of information between their increasing numbers of branches in various parts of the world. This has made bandwidth a very fundamental resource in service delivery. Bandwidth incurs high recurrent costs on an organization and in some cases adequate bandwidth is not sufficient. This has called for optimization of the available bandwidth so as to provide optimal services.

There are a number of optimization techniques which have been deployed by many organizations and more are being tested in labs and researched on. Some of the technologies which are already in place include load balancing, de-duplication, web caching, compression, wide area file services, TCP flow and path optimization among others. These methods have been combined in various cases to provide optimum bandwidth performance while considering the quality of the services and data sent across the network.

The emerging trend in WAN optimization aim at increasing the bandwidth utilization by a significant margin for instance achieving up to four times the capacity of any given bandwidth as compared to when it is not optimized. The most common emerging technologies focus on the developing technological platforms. A common platform is the use of mobile technology. Today in Africa, there is increased use of smart phones which is even expected to increase further. Organizations have allowed their employees to access data and other systems over the mobile devices. This requires extremely optimized WAN to ensure efficient service provision. The increase in the number of mobile devices is likely to pose pressure on the bandwidth and thus organizations are exploring other optimization techniques as they envisage the bandwidth demands.

Cloud based optimization techniques such as use of public and private clouds that are customized for optimum performance. These techniques ensure that the services and data is accessed easily within a short time. The future of network optimization is towards hybrid mechanisms of WAN optimization that combines a number of techniques to arrive at the most optimum operating levels. These may include use of compression and load balancing or more.

### 5.2.2 Simulation Results

The simulation results shown in chapter four shows that there is a clear difference between the performance of an optimized and non-optimized network. The simulation used a number of optimization techniques that are coupled and as WAN optimization controller and gave distinct results.

From the results, it can be concluded that for a similar bandwidth, the amount of data sent and received are high for optimized network as compared to a non-optimized network. This is an indicator that, optimized network has a higher efficiency and more data is able to pass through the same bandwidth within the same timeline. This is an increased throughput

for the network. Further, the amount of data packets dropped for an optimized network is lower in comparison to the non-optimized one. This shows that there is little distraction of data while it is on transit between the two WANS. Data packets are dropped when they are taking too long to reach at the destination and consequently they are dropped.

## 5.3 Recommendation

In this study, there were numerous lessons learnt as well as crucial information gathered which would go a long way in improving plans and strategies relevant to this field of technology. The performance of an optimized network has been found to be excellent; a knowledge which is fundamental to various stakeholders including managerial teams, the government and academia. Further the Internet services providers are informed of the current status of the WAN optimization and the envisaged development that aim at improving service provision. The Kenyan public sector will also benefit from this study in many ways.

### 5.3.1 Managerial and Policy Makers

Managers and policy makers, being the decision making organ in an organization, can find the findings from this study useful in a number of ways. First, the study points out that that WAN optimization is a fundamental aspect of performance that greatly influences customer satisfaction and organizational output. This is an important aspect since it is synonymous to compliance to the set standards and boosts the morale of both employees and customers.

Secondly, the research has indicated the various techniques and tools to employ in optimization of WAN. Further the study gives the current trends and forecasts on the future developing technologies of WAN optimization. This information is significant to management so that they can put in place technological strategies which aim at placing an organization at par with the current technologies. The information from the research therefore can be used by management in preparation of strategic plans and budgetary allocations. The

research also provides pointers of the areas which needs improvement on the technological infrastructure of an organization.

### 5.3.2 Consumers of ICT services

Most ICT services reaches the end user; customer through WAN by most organizations. The study helps in improving the performance of WAN; the platform through which consumers get services. This helps them to understand the areas that they need to input their suggestions and make proposals for overall improvement of WAN infrastructure used by service providers. The users can also help the ICT service providers both within and without to ensure that the WAN infrastructure that they are using meets the current technological levels and best suits provision of ICT services

### 5.3.3 The Government

Most governments provide services to their citizens in all parts of the country. As a result ministries and all other government agencies have opened their branches across the country. These services are accessed from central data centers, strategically located. All the offices access the services and store their data on these centralized systems. This study has highlighted the difference between optimized and non-optimized networks. Most government institutions have almost similar operations which require use of WAN services and as a result they could benefit from this study.

### 5.3.4 Academia

This research topic is one of the less researched areas thus it provides the much needed literature and methodology in this area of research. The world of academia, can apply similar models in other infrastructural facilities that demand areas and other institutions, especially in other fields of the public sector which have different operations as far as acquisition and provision of ICT services are concerned.

From the literature review it was found out that there are numerous mechanisms of WAN optimization, however only a view of those mechanisms were experimented in this study. Little research has been done on optimization of network resources by organizations and institutions of higher learning. There is need therefore to carry out more research and develop various models which can be implemented in the industries and improve the technology. There is need for researchers to undertake further research focusing on optimization and continuous improvement of data storage and transmission as well as performance and access of applications across large networks.

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