



**University of Fort Hare**  
*Together in Excellence*

**Improving the Robustness and Effectiveness of Rural Telecommunication Infrastructures  
in Dwesa South Africa**

**A thesis submitted in fulfilment of the requirements of the degree of**

**Master of Science**

**in**

**Computer Science**

**by**

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## **Declaration**

I, the undersigned declare that the work contained in this dissertation is my own original work has not previously in its entirety or in part been submitted at any educational institution for a similar or any other degree awarded. I acknowledge that all references are accurately recorded and that, unless otherwise stated, all work herein is my own.

Signature.....

Date.....

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## **Dedication**

This thesis is dedicated to my parents who made me believe I was always the best who deserved the best.

## **Abstract**

In recent years, immense effort has been channelled towards the Information and Technological development of rural areas. To support this development, telecommunication networks have been deployed. The availability of these telecommunication networks is expected to improve the way people share ideas and communicate locally and globally, reducing limiting factors like distance through the use of the Internet. The major problem for these networks is that very few of them have managed to stay in operation over long periods of time. One of the major causes of this failure is the lack of proper monitoring and management as, in some cases, administrators are located far away from the network site. Other factors that contribute to the frequent failure of these networks are lack of proper infrastructure, lack of a constant power supply and other environmental issues. A telecommunication network was deployed for the people of Dwesa by the Siyakhula Living Lab project. During this research project, frequent visits were made to the site and network users were informally interviewed in order to gain insight into the network challenges. Based on the challenges, different network monitoring systems and other solutions were deployed on the network. This thesis analyses the problems encountered and presents possible and affordable solutions that were implemented on the network. This was done to improve the network's reliability, availability and manageability whilst exploring possible and practical ways in which the connectivity of the deployed telecommunication network can be maintained. As part of these solutions, a GPRS redundant link, Nagios and Cacti monitoring systems as well as Simple backup systems were deployed.

## Acronyms

AC	Access Concentrators
AMANDA	Automatic Marylyn Network Disk Archiver
CDMA	Code Divison Multiple Access
CGI	Common Gateway Interface
CSIR	Council for Scientific and Industry Research
DHCP	Dynamic Host Configuration Protocol
EVDO	Evolution Data Optimized or Evolution Data Only
FDD	Frequency Division Duplexing
FOSS	Free and Open Source Software
FTP	File Transfer Protocol
GPRS	General Packet Radio Service
GSM	Global System for Mobile
GUI	Graphical User Interface
HARQ	Hybrid Automatic Request
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HTTP	Hyper Text Transfer Protocol
ICT	Information and Communications Technology
ICT4D	ICT for Development
IDU	Indoor Unit
IP address	Internet Protocol address
LAN	Local Area Network
LEOs	Low Earth orbiting satellite
LOS	Line Of Sight
LTE	Long Term Evolution
LTSP	Linux Terminal Server Project

MAC	Medium Access Control
MRTG	Multi Router Traffic Grapher
NLOS	Non-Line-Of-Sight
NMS	Network Monitoring Software
ODU	Outdoor Unit
OFDM	Orthogonal Frequency Division Multiplexing
OFDM	Orthogonal Frequency Division Multiplexing
PDU	Protocol Data Units
PPPoE	Point to Point Protocol over Ethernet
RTT	Round Trip Time
SAE	System Architecture Evolution
SDU	Service Data Units
SLL	Siyakhula Living Lab
SNMP	Simple Network Management Protocol
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
UPS	Uninterruptible Power Supply
VoIP	Voice over Internet Protocol
VSAT	Very Small Aperture Terminal
WAN	Wide Area Network
WCDMA	Wideband Code-Division Multiple Access
Wi-Fi	Wireless Fidelity
Wild Net	Wi-Fi-based Long Distance Networks
WiMAX	Worldwide Interoperability for Microwave Access
WOL	Wake on LAN

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**Related Publications:**

Memory Munashe Ranga, Alfredo Terzoli and Mamello Thinyane: Improving the Robustness and Effectiveness of Rural Telecommunication Networks: Dwesa Case Study: SATNAC 2008.

Memory Munashe Ranga, Mamello Thinyane and Alfredo Terzoli: Exploring Cost-Effective Reinforcements for Rural Telecommunication Networks: Dwesa Case Study: SATNAC 2010.

## **Chapter One: Introduction**

### **1.1 Introduction**

Research has shown that Information and Communication Technologies (ICTs), particularly new ICTs, contribute to improving the living standards of people in marginalized areas (Galperin, 2005; Jeremy, 2001). ICTs contribute to people's lives by helping them stay well informed on subjects such as agriculture, education, and governance. As people become familiar with ICTs, they discover the opportunities that these tools offer and express their needs on the basis of the estimated usefulness of these technologies (Hack, 2005; Galperin, 2005). To necessitate the provision of ICT services, we have deployed a telecommunication network that provides different services for the people of the Dwesa community. The deployed network infrastructure allows the development of different ICT services within the community. Of course, the network exists for the Dwesa community, but there are different problems that are currently experienced on the network. In this study we identify some of the common problems on the network and discuss some solutions we have implemented to overcome these problems.

This chapter provides an introduction to the research being undertaken and the research site. It highlights the problem statement. The chapter further discusses the aims and objectives of this study. Furthermore, a discussion on the contribution of the research to the different telecommunication networks deployed in South Africa is given. This chapter also outlines the underlying assumptions and the limitations of this study.

### **1.2 Project context**

The research was conducted on the Siyakhula Living Lab (SLL) network. This network is deployed in Dwesa. Dwesa is an area with characteristics that are similar to those of other rural areas in Africa (Palmer, 2002). It is located on the Wild Coast region of the Eastern Cape Province of South Africa (Palmer, 2002; Timmermans, 2004). This community is under the Mbashe Municipality which belongs to the Amatole region whose main office is based in East London (TRALSO, 2007). Willowvale, 50km away from Dwesa, is its closest neighbouring town. This area lacks basic infrastructure such as, telecommunications facilities, running water and tarred roads, although there have been recent improvements to the infrastructure (Dalvit *et. al*, 2007; Palmer, 2002). Electricity has been present in homes since December 2009.

SLL is a project which is managed by two universities, the University of Fort Hare and Rhodes University, located approximately 300kms from the SLL site. The SLL project is part of the broader Information and Communications Technology for Development (ICT4D) endeavour, within South Africa. The aim of the SLL project is to develop a cost effective and robust telecommunications platform for rural and marginalised areas in South Africa (COFISA&DST, 2008). There are projects that are currently running on the deployed network as well as others that are under construction. Some of the deployed systems include a Help desk system, an e-Health system, e-Judiciary and e-Government. This study focuses on the ways in which the robustness and effectiveness of the underlying deployed network can be improved.

### **1.3 SLL deployed network**

The existing ICT platform is deployed in four schools, namely; Mpume, Ngwane, Mtokwane and Nondobo as shown in Figure 1.1. All four schools are within the Dwesa area (Dalvit *et. al*, 2007; Mandioma, 2007). There is also a Worldwide Interoperability for Microwave Access (WiMAX) unit which establishes the wireless to the other schools and other equipment that includes a server running (LTSP, HTTP, and MySQL), personal computers, Access concentrator, a DLink switch and a Voice over Internet Protocol (VoIP) phone (Dalvit *et. al*, 2007).

A WiMAX micro-base station is located in Ngwane which is the highest point within the community and the transmission of signals from here is affected by fewer obstructions (Siebörger *et al*, 2010). The WiMAX link on this school establishes the connection between Mpume and other schools on the network. At Ngwane there is an Alvarion WiMAX micro-base station that makes use of 256 Orthogonal Frequency Division Multiplexing (OFDM) carriers and modulation (Siebörger *et al*, 2010). This micro-base station supports a bandwidth of 14MHz, its uplink ranges from 3.5MHz up to 3.4 MHz and its downlink is 3.7 MHz (Siebörger *et al*, 2010).

For the WiMAX network there are Distributed Access Nodes (DANs) at each of the four schools. Each DAN has a community access point (CAP) which provides access to the local loop WiMAX network for all the clients at each site. The CAP runs on a FreeBSD router and is configured in such a way that it manages the DAN using different services such as Netflow, SMTP SMNMP and others. This FreeBSD router (CAP) also acts as a gateway



between the LAN within the school and the local loop access network which connects to the Internet through the Telkom VSAT (Siebörger *et al*, 2010). Apart from the DANs and the CAPs at each school there is also a customer premises equipment (CPE) unit that connects back to the micro-base station at Ngwane and, therefore, allows traffic to be channelled amongst the schools (Siebörger *et al*, 2010; Mandioma, 2007).

The other equipment deployed at these schools includes a switch rack (wall mounted), a switch, personal computers, a server (Asterisk, DHCP (Dynamic Host Configuration Protocol)) and a VoIP (Voice Over Internet Protocol) phone (Dalvit *et. al*, 2007; Siebörger *et, al*, 2007).

At Mpume, a Very Small Aperture Terminal (VSAT) is deployed. The VSAT network at Mpume connects the other three schools to the internet (Dalvit *et al*, 2007; Mandioma, 2007). At this school, there is an Access concentrator (AC) which terminates the Point to Point Protocol over Ethernet (PPPoE) connection for the schools within the SLL network since all these schools rely on the AC for access to the Internet (Siebörger *et al*, 2010). At the same time, Mpume relies on the micro-base station at Ngwane in order to make use of local services such as VoIP and access to shared resources (offline content), such as the Dwesa Wiki (Siebörger *et al*, 2010).

Figure 1.1 illustrates the infrastructure of the ICT platform already deployed at Dwesa. The diagram also shows the IP addressing scheme of the infrastructure and links between the servers, VoIP phones and personal computers.

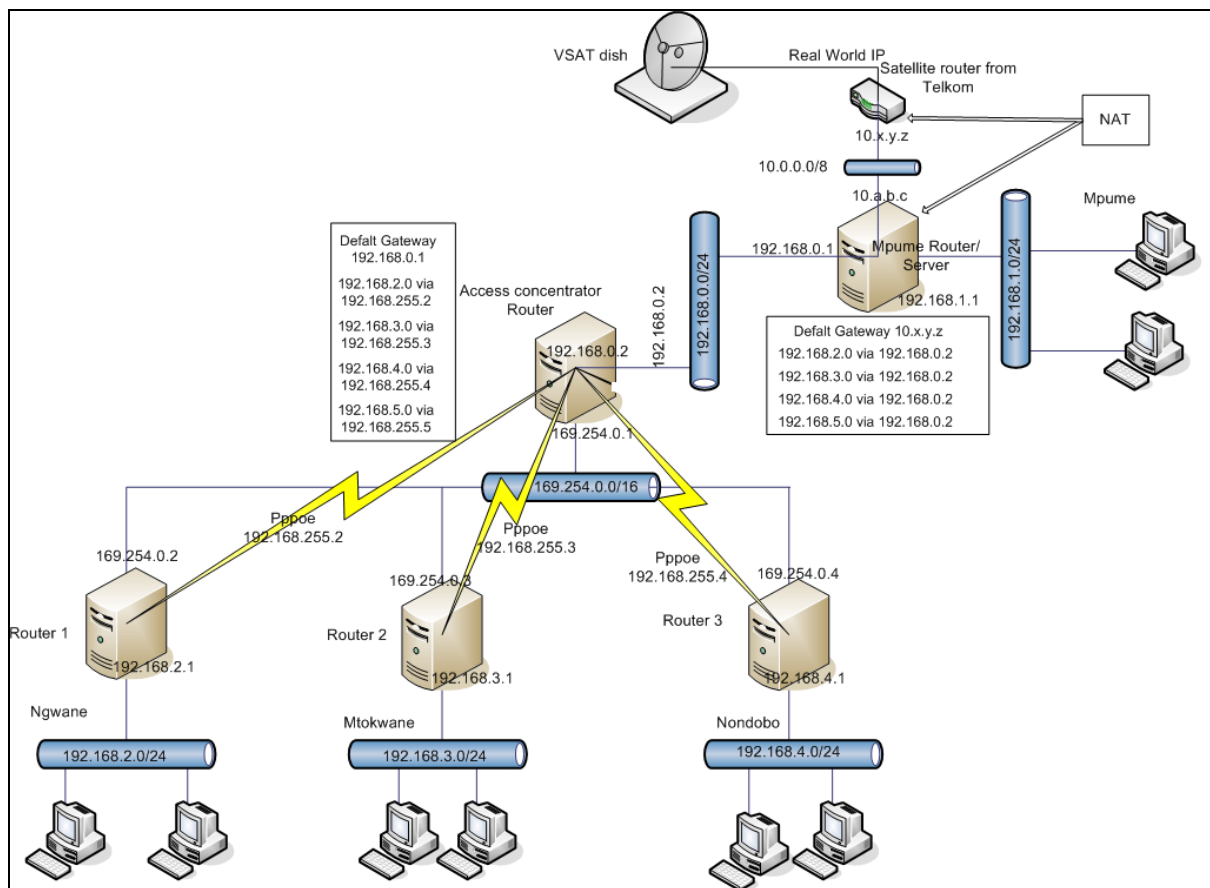
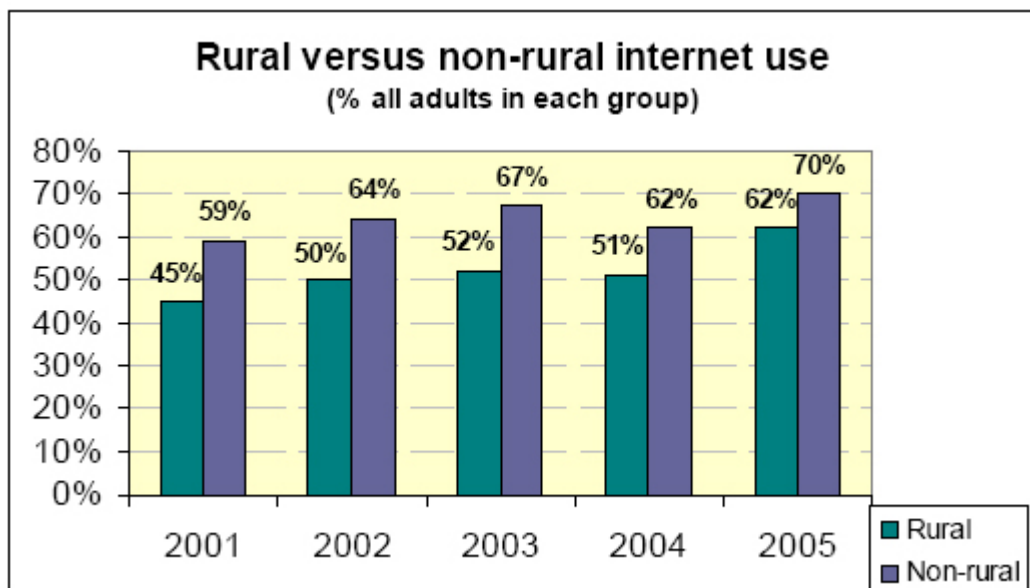


Figure 1.1: SLL network diagram

## 1.4 Background

Figure 1.2, below, shows the ratio between internet usage and the South African population in 2008. These figures have continuously increased and, based on the internet growth, there is a need to have reliable network infrastructures. As of 2009, studies have shown that 4.6 million South Africans now have access to the internet compared to the 3,590,000 users in December 2008 (Internet Usage and Marketing Report, 2008). The Department of Education is also working towards connecting 5300 schools by 2013 (DoE White Paper, 2010). The rapid growth in the number of Internet users has resulted from the development of different new types of networks that can support a large number of users. These new networks have also added value such as cost decrease, engineering efficiency increase and accessibility through standardisation of internet usage (DoE White Paper, 2010). It is therefore important that different methods and solutions are put in place to increase the performance and robustness of these new types of networks.



*Figure 1.2: South African population and Internet usage (Internet Usage and Marketing Report, 2008)*

As shown in Figure 1.2 the percentages of adults using of internet in rural areas from 2001 up to 2005 is lower than the percentage of users in urban areas. Hence, in attempting to enable connectivity in rural areas, companies like Vodacom have been giving out cheap GPRS modems to rural schools in South Africa that have GPRS coverage (Peiter, 2009). However, studies and follow ups have shown that these networks have not been operational after deployment since the users lack the requisite technical experience to operate the modems (Peiter, 2009).

Despite the effort of improving telecommunication and connectivity in rural areas, various challenges continue to be experienced on these deployed networks; an example of these challenges is the lack of electricity, since the majority of the rural areas do not have electricity (Van der Plas, 2004). Other challenges include a lack of awareness within the community, on the use and application of telecommunication networks, and the vandalism of equipment (Westerveld, 2002).

There is a need for the networks to be fully monitored in terms of their performance, availability and reliability. Most networks fail to meet their targeted objectives as a result of various challenges and problems experienced by rural networks.

## 1.5 Problem statement

Rural networks face problems such as shortage of resources, lack of reliable electrical supply, and lack of well trained people who have the knowledge of how to operate and maintain the deployed network (Surana, 2007). A number of networks are currently being deployed for rural communities. However, they face challenges in three functionalities; these are:

*Availability* The availability (uptime) of these networks is very limited due to loss of connection and lack of skill. Other reasons will be discussed in detail in the next chapter.

*Accessibility* Most of the rural networks are deployed in areas where people have limited access. For example, if the networks are placed at schools, the people in the community only have access to the infrastructure when the school is open. This becomes a challenge when students are on holiday or over weekends when most of the people are free because they cannot access the internet resources at their own convenience.

*Reliability* Due to lack of skill, erratic power supply, harsh weather conditions and various other reasons that are discussed in the next chapter, the networks deployed in rural areas are very unreliable.

Other technical problems that are faced by networks deployed in rural areas include lack of monitoring systems. A detailed list of network problems faced by the SLL network is available in *Appendix 1*. An analysis of the problems is covered in Chapter 4. Hence, it is essential that the deployed telecommunication networks be properly monitored and improved so as to increase its availability and reliability. This eventually improves the availability of Internet connectivity within marginalised areas.

## 1.6 Research aims and motivation

The aim of this research is to analyse the problems as they occur on the SLL network and come up with feasible solutions that make the network resilient to failure. As part of these solutions, monitoring systems are deployed on the network. These monitoring systems help keep an eye on the network. Another objective of this research is to introduce a redundant link and a backup system to improve the availability of the network. The introduction of these

various technologies, and other social and organisational rules, improves the network's reliability, performance and communication with the people in the community and their access to various services offered by the network.

The introduction of ICTs, through the use of telecommunication infrastructure, is becoming a key area in terms of rural development in developing areas (Shah, 2007). The research initiative signifies the beginning of efficient and cost effective ways in which the robustness and availability of the deployed network can be improved. The success of the solutions implemented on the SLL network can be used and applied to telecommunication networks similar to the one deployed in the SLL project. This study also promotes and improves connectivity in rural and marginalised areas. It also enhances communication between users and administrators.

## **1.7 Research Methodology**

Since the network was deployed in 2006, there has been frequent communication between the users and the network experts (administrators) concerning the challenges on this network. This communication was done in the form of emails and phone calls. To get a clear picture of the frequent network problems, a network diary was compiled from the Dwesa mailing lists with all the problems that were experienced on the site, from 2008 to 2010. From this diary it was realised that there was little variation in the types of problems over the years. For this particular study, main focus was put on those problems that were reported from 2008 to 2010. Apart from the problems gathered from the mailing list during this period, frequent visits were done to the network site to understand the network architecture and observe the performance of the network. Informal interviews were conducted with the users on the sites as a means of understanding and gathering information on other problems they faced, apart from those that were communicated on the mailing list or through phone calls. A detailed description of these problems and the various categories of the problems are covered in chapter 4. Chapter 5 discusses the solutions that were implanted to address the problems discussed in chapter 4.

## **1.8 Definition of key terms**

*Robustness:* In this research we define robustness as the ability of a deployed network to perform well under usual and unusual circumstances, that the network could be exposed to. In the same context, the functionality of the network should be easy to understand.

*Effectiveness:* In this research we define effectiveness as the ability of the network to fulfil its primary purpose which includes providing ICT services to rural people.

## **1.9 Motivation and contribution of this research**

Since the introduction of ICTs through the use of telecommunication infrastructure, is becoming a key area in terms of rural development in developing areas. The solutions implemented on the SLL network as well as others that have been discussed in the thesis can also be applied and implemented on networks that are similar to the one deployed in the SLL project.

## **1.10 Structure of the thesis**

The rest of this thesis is structured as follows:

Chapter 2 offers a detailed explanation of the deployed network and discusses other living labs that have deployed networks which are similar to the one deployed on the SLL, as well as the different problems they face. In this chapter we discuss the solutions that these different projects have implemented to overcome their various problems.

Chapter 3 provides a brief discussion of the network/access, monitoring and backup technologies that are used on other telecommunication infrastructures as well as those that have been deployed on the SLL network.

Chapter 4 explains the different problems that have been experienced by the SLL network which motivated this research. It then moves on to discuss the solutions that have been implemented to solve these problems and other feasible solutions that were not implemented during the course of this research.

Chapter 5 includes testing, evaluation and experimental results. This chapter evaluates the research project and shows the test results that were obtained from various systems that were deployed as part of the network solutions. The results shown in chapter five give a summarised reflection of how the network monitoring system was performing during the experimental period. The detailed results can be found on the server in Dwesa.

Chapter 6 offers a final discussion of the results and concludes the study. This chapter provides an overview of what has been achieved together with a brief summary of the thesis. It further explains the ideas that have been considered for future work in order to improve the SLL deployed network.

## **Chapter Two: Related Work**

### **2.1 Introduction**

This chapter describes the different services that have been introduced by various Information and Communications Technology for Development (ICT4D) projects. It further discusses the roles that these services have played in marginalised areas. The chapter provides a detailed literature review on rural networks, problems faced and ways that have been suggested to improve such networks. Furthermore, this chapter discusses other telecommunication networks that have been deployed in rural areas of South Africa, and in other developing countries. The different network challenges that are faced by these networks and various mechanisms that the administrators have implemented, in trying to overcome these network challenges, are also discussed here. Finally, an analysis of case studies related to this research is also offered.

### **2.2 The role of ICT4D projects in marginalised areas**

ICT4D deals with the use of new and existing technologies to broaden the use of communication and information resources (Jenkins, 2007). It also facilitates access to Information and Communications Technology (ICT) resources and promotes their effectiveness (Pitke, 2007). The introduction of ICT4D projects has improved the lives of rural people by providing different services such as e-health facilities and e-commerce platforms (Jenkins, 2007; Nikolidakis, 2006).

The introduction of ICTs has improved the quality of life for people in these marginalised and rural areas. It has also opened various ways in which rural people can overcome problems that have affected their progress in terms of business, communication and, to a great extent, education (Wire, 2007). Productivity, better health, education and government services are some of the key areas that have been improved as a result of ICT projects (Jeremy *et al*, 2001; Wertlen, 2007). The availability of the Internet and other ICTs has helped to improve the quality of communication for the people in marginalised areas since they can now communicate with people from the urban areas (Wire, 2007).



The introduction and deployment of telecommunication networks in rural areas has been quite a challenge in many rural areas due to several environmental and financial constraints that are experienced in rural areas (Laudon, 2005).

The combination of wired and wireless technologies has raised new opportunities for the sustainability of Internet connectivity in the rural areas of the developing world (Surana, 2004; Subramanian *et.al*, 2006). The different technologies have greatly reduced the cost in deployment. These technologies have been adjusted to suit the demand for ICT services in rural areas. As a result, they enable the sustainability of the networks (Galperin, 2005; Surana *et.al*, 2004).

Despite the introduction of the Internet, the deployment of telecommunication networks has, in other cases, improved the quality of life for people living in rural areas. Some of the benefits are discussed below, as highlighted by (Jenkins, 2007; Rowley, 2000):

- Creating employment among the inhabitants through the creation of small businesses and micro enterprises;
- Constant communication between the people in the rural areas and those ones from the urban areas through the use of Voice over Internet Protocol (VoIP) phones and access to the outside world;
- Improving the health and well being of the community people since they will have access to extension services such as telemedicine, remote diagnosis and treatment advice on different kinds of diseases. Exposure to different kinds of businesses through the use of E-commerce platforms;
- Strengthening the educational system through e-learning and distance learning.

As a result of these benefits many countries have tried to fully utilize such benefits leading to better telecommunications connectivity.

A remote Very Small Aperture Terminal (VSAT) station with local distribution based on Code Division Multiple Access (CDMA) or Time Division Multiple Access (TDMA) techniques have been used to interconnect the remote locations in some developing countries. India has a VSAT based network, which they call INFLIBNET. They use this network for interconnecting University Libraries across the country. Each station is connected to a LAN (Subramanian *et. al*, 2006). This network can be easily adapted and expanded, for Internet

connectivity, to all the Universities.

The establishment of satellite based services such as the world wide personal communication services using a Low Earth Orbiting satellite (LEOs), the telephone and the wireless technology have opened new ways of achieving cost effective Internet networking on the AirJaldi and Aravind telecommunication networks (Surana *et.al*, 2007; Socher, 2009).

### **2.3 Characteristics of rural areas**

In any developing country, the characteristics and challenges faced by people staying in rural areas are almost the same (Pitke, 2007). Some of the key characteristics are shown below, as highlighted by (Pitke 2007; Jenkins 2005):

- Lack of basic facilities such as water, proper roads and reliable electrical supply;
- Lack of technically skilled people;
- Environmental obstructions such as hills and valleys, making the construction of telecommunications networks very costly;
- Bad climatic conditions which, as a result, cause damage to the equipment.

In rural South Africa, telecommunication networks have been deployed at schools since they are believed to be the central points of contact where people are free to go and make use of the available resources (Werner *et al*, 2006).

This is the case with the Siyakhula Living Lab (SLL) network where the network has been deployed at schools. In rural areas, schools are one of the places that are fairly secure and, in other cases, they are the only places with electricity. Despite these positive characteristics, rural schools also have weaknesses which separate them from urban schools. Consequently, there are various issues that the rural schools should overcome besides the introduction of ICT (Herdberg, 2002; Werner *et al* 2006). Some of the problems that are faced by schools in rural areas are:

- *Lack of computer hardware and software*- Rural schools are, in most cases, remotely located and as a result the provision of computer hardware and software resources is scarce since many organisations focus on the urban schools. Due to this factor, students from these schools are not familiar with the use of computers when they go to tertiary institutes as well as various work places (Jenkins, 2005);

- *Lack of telephone facilities*- Schools in the rural areas still rely on old fashioned modes of communication like writing letters or word-of-mouth. This is a result of no telephone facilities (Jenkins, 2005). So, the introduction of telecommunication infrastructures can develop their modes of communication;
- *Lacks of technical training*- Rural communities have very few technically skilled individuals with experience in computer and internet usage. Hence, students are lacking in these skills, which are sometimes necessary when they undertake university studies (Jenkins, 2005);
- *Lack of library facilities*- The educational systems greatly depend on the use of libraries and, unfortunately, this facility is not available in rural communities. Therefore, the students do not develop the culture of reading at a young age. This becomes a problem when they have to move to higher educational levels where they have to make use of library facilities (Hawkins, 2007; Socher *et al*, 2009).

Apart from the problems mentioned above, rural schools do not have a constant power supply. The people in rural areas also do not have proper government and health services. The introduction of ICTs has helped to improve the way of life of these people (Wire, 2007).

## **2. 4 Problems experienced in ICT4D projects**

The rural characteristics identified in section 2.3 affect the way in which the deployed networks function and the different challenges they face. Few network systems that have been deployed in rural developing regions have managed to run over long periods (Surana *et.al*, 2004). The reasons for these network failures differ from one area to another. In some cases, network components fail as a result of poor electricity and bad weather conditions (Surana *et.al*, 2004).

The damage experienced by the equipment varies depending on the amount of AC transmitted to the equipment. As a result of these factors, rural networks have lost valuable equipment like routers and servers (Surana *et.al*, 2004; Surana *et.al*, 2007).

Another challenge that these networks face is finding solutions that are sustainable and cheap at all levels of the system (Surana *et.al*, 2004). In some cases, the failure of a single point on the network has led to the whole network not working at all. These network problems

develop from something fairly simple to being complicated, since more damage is done when local staff members try to fix the problems without establishing the core cause. Other problems experienced in ICT4D projects are:

*Difficulty in fault diagnosis-* Since network users in rural areas are usually less technologically skilled, they are bound to misinterpret the faults that occur on the network; this is the case in Tsilitwa as well as the SLL network which will be discussed in further detail later in this chapter. A common description of a fault by Aravind network users is “the internet is down” (Surana *et.al*, 2004). The lack of technically trained staff, coupled with unreliable systems, tend to limit monitoring and forestall an accurate diagnosis (Patra *et. al* 2004; Surana *et.al*, 2004).

The correct interpretation of network problems can save time and prevent unnecessary travel (Surana *et.al*, 2007). In other cases, network users do not fully understand the way the equipment is supposed to operate and, as a result, it becomes even more difficult for them to notice or report when a problem occurs (Surana *et.al*, 2007).

*Fault anticipation-* Planning for network problems is not always possible since the anticipation of a fault is very difficult on these networks because, in most cases, there is limited or no remote monitoring capability on the networks (Surana *et.al*, 2007). Hence, urgent visits are made because, in most cases, the equipment breaks or the network unexpectedly goes down.

However, there are some general problems experienced by rural networks, such as a lack of proper maintenance, no ownership and deliberate switching off of equipment by users. These factors also affect the performance and availability of the deployed networks.

*Unstable power supply-* The power supply in most rural areas is not stable and this has limited the availability of telecommunication infrastructures in rural areas (Ana, 2005).

*Lacks of skills-* Many technically skilled people in rural areas migrate to urban areas in search of a better life and, hence, the people that remain in the rural areas do not have sufficient knowledge on the use of ICT infrastructures (Surana *et.al*, 2007; Ana, 2005).

*Difficult terrain-* The terrain in most rural areas is hilly and, as a result, relaying signals such as Microwave UHF over long distances becomes a significant challenge. This further limits the use of wireless networks in these areas (Ana, 2005).

*Remote location-* Rural areas in most parts of Africa are located far from the towns and, as a result, when a problem occurs it is difficult to send experts to repair the fault. Consequently, fault restoration time is increased (Surana *et.al*, 2007; Ana, 2005).

These network problems are similar in all rural areas. Of course, different solutions have been suggested to overcome the above problems for the SLL network, this is discussed in detail in Chapter 4 of this study.

## **2. 5 Measures to sustain ICT4D projects in marginalised areas**

To overcome the above mentioned problems, networks in rural areas as well as those in urban areas have deployed redundant routes to improve the availability of the networks, network monitoring systems and other social rules that govern the use of the equipment.

*Network monitoring systems-* Every network should be monitored either locally or remotely or in both ways (Surana *et.al*, 2004). The reason for this is to ascertain the status of all the devices used in the computer network (Bhaskaran *et. al*, 2007). The Network Monitoring Software (NMS) covers a number of areas such as the downtime of the servers, backing up of important files daily, graphical overview of bandwidth consumption and others (Bhaskarane *et. al*, 2007). These systems constantly monitor the network remotely or locally and inform the administrator as soon as it finds a malicious activity or any problem developing (Bhaskaran *et. al*, 2007; SNIPS, 2001). Apart from monitoring systems, networks now make use of backup systems to keep their critical configurations. Some of the backup systems that are commonly used include simple backup and Amanda. These will be discussed in detail in the next chapter.

*Security of equipment-* Servers, routers, switches and other key network equipment should be fitted with a battery to ensure that they does not crash during power failures (Solar Electric Fund, 2001). Uninterruptible Power Supply (UPS) units cost, on average, about R1500 in South Africa and they are not cheap enough for people in rural areas to buy. Hence, it becomes a good investment in the long term because it will host many pieces of equipment at the same time (Holtz *et. al*, 2007; IT Operations, 2003). At the same time,

some organisations have put up rules that govern the use of the equipment and well trained people have been put in charge of the network (Holtz *et. al*, 2007).

*Training-* The people in the rural areas should be educated on the benefits of using different ICT infrastructures and basic computing concepts. As part of their training, these people should be exposed to different ICTs that can improve their socio-economic conditions. Apart from offering training, project heads and network administrators should support and encourage a sense of ownership of the equipment and the deployed infrastructure amongst the people within the community (Beyers, 2008; Surana *et.al*, 2007).

*Erratic power supply-* Apart from the use of UPSs, the networks in rural areas can use other forms of energy such as solar energy and biogas (Beyers, 2008). This will enable the network to continue functioning even when there is no power in the area.

The problems discussed in this section have been experienced by most of the networks deployed in rural areas. Below is a discussion of the use of telecommunications in Africa.

## **2. 6 Telecommunications in Africa**

The use of telecommunication technologies depends on their cost in terms of buying the equipment and deploying it. The availability of telecommunication networks is better in urban areas since they have means of generating income and can afford to deploy and use the different telecommunication facilities (Oyedemi, 2008). For example, the demand for landline telephones decreased due to an increase in the use of cell phones in urban areas. In 2007, landline usages decreased from 24.4% to 18.6% while the use of cell phones increased by 7.3% (ITNewsAfrica, 2010). This increase cannot be compared to the high connectivity levels in countries such as Nigeria (Yusuf, 2010). Nigeria has one of the highest populations in Africa and 28.9% of the population have an internet connection. It also accounts for 36.8% of Africa's current internet population, placing it strides ahead of other countries like South Africa and Egypt (Mwathi, 2009; Yusuf, 2010).

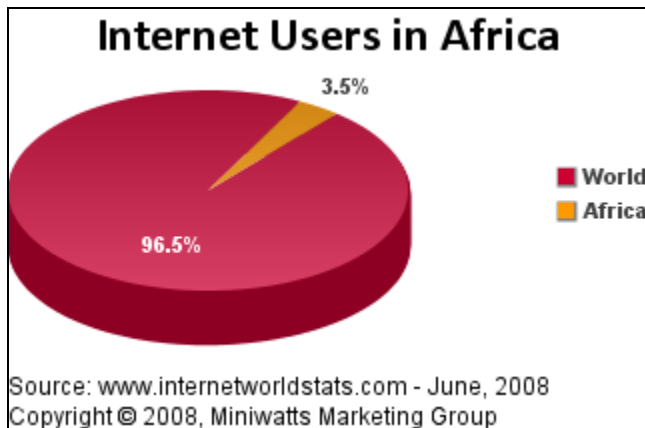


Figure 2.1: Internet connectivity in African countries adapted from (Mwathi 2009)

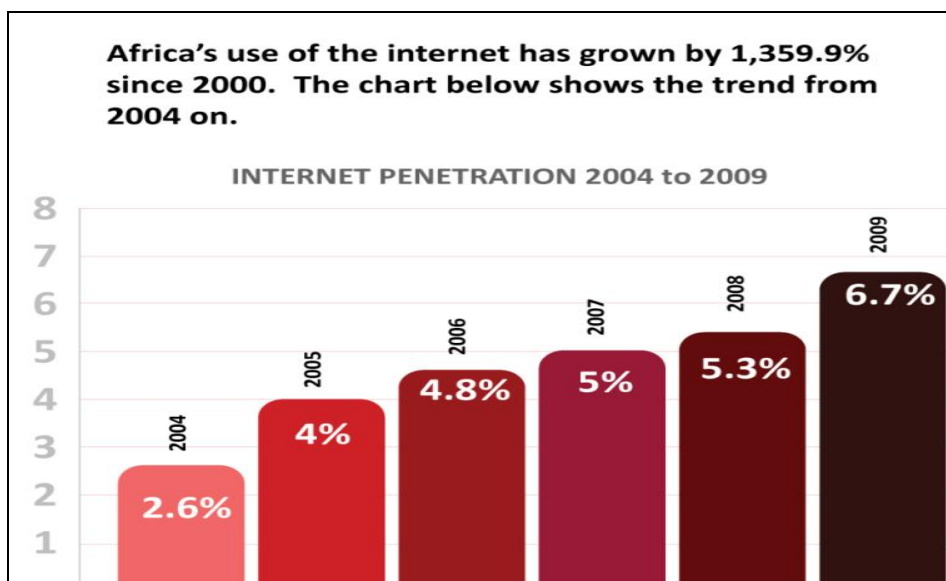


Figure 2.2: Internet penetration trend (InternetWorldStats, 2009)

Figure 2.2 shows the gradual increase in connectivity from 2004 to 2009. This shows that over the past years there has been an improvement in terms of internet connectivity from 2.6% to 6.7 % of the total population which implies that more telecommunication networks are being deployed in African countries (InternetWorldStats, 2009). However, these networks have experienced several problems, depending on their location.

## 2. 7 Telecommunications in South Africa

The Department of Communications has also made efforts to improve telecommunications in South Africa. They have developed different strategies that they believe can improve

telecommunications in South Africa; these include a broadband strategy which aims to provide a reliable, cost-effective and easily accessible ICT broadband infrastructure (Smith, 2009). To support this strategy the Department of Communication has taken part in the New Partnership for Africa's Development (Nepad) ICT Broadband Infrastructure Network for Africa, which includes the Eastern Africa Submarine Cable System (EASSy) project. The EASSy cable project is an arrangement between the South African and Sudanese governments (ITNewsAfrica, 2010; EASSy, 2008).

### **2. 7.1 Service Providers' Initiatives**

Despite the high cost of equipment, various service providers are going to great lengths to increase connectivity in South Africa (South Africa's Telecommunication, 2008). Telecommunication companies such as Telkom, Neotel and Saab Grintek have started projects that aim at improving connectivity in rural areas. For example, Telkom has deployed WiMAX networks in urban parts of South Africa with speeds of 70Mbps and Neotel has introduced flexible and easy to use services that can be used in urban areas; this is called NeoFlex Data (South Africa's Telecommunication, 2008). It has peak speeds of 3.1Mbps (downloads) and 1.8Mbps (uploads) and connects to the internet through Ethernet and Wireless LAN (South Africa's Telecommunication, 2008).

### **2. 7.2 Government Initiatives**

The government has taken initiatives that will allow rural communities to access the Internet (USAASA, 2008). The Universal Service and Access Agency of South Africa (USAASA) is one of the organizations, established and working under the regulatory and policy framework within the Telecommunications Act No. 103 of 1996, as amended in 2003 (USAASA, 2008). USAASA aims to promote the goals of universal service and universal access (USAASA, 2008). The universal service is a reliable connection to the communication network that enables any type of communication within any part of South Africa (Mandioma, 2007).

## **2. 8 Case Studies of Telecommunications projects**

The idea of telecommunications projects is growing into a reality in most developing countries. Listed below are some of the projects that are already in operation around the world. These case studies describe and explain the structure of rural networks and the methods applied to enhancing network performance. This enables the creation of the best



possible solutions that can be implemented in order to increase the robustness and effectiveness of the SLL network.

### **2. 8.1 Ulwazi project**

Rural schools still face challenges in terms of the availability of reliable electricity, ICT resources and technically skilled teachers (Jenkins, 2003). In certain areas of South Africa, users have access to computer resources but, due to the unbalanced ration between computers and the users, there is limited access to these resources.

To overcome these challenges the Ulwazi project was started. In this project, a broadband Motorola Canopy network was deployed to connect four schools in Pretoria, South Africa (Beyers, 2008). This network has improved the life of people within this community since resources can now be shared between the four schools and there is a sharing of information between the students and the teachers from these schools. Below is the network diagram showing how the schools are connected (Beyers, 2008).

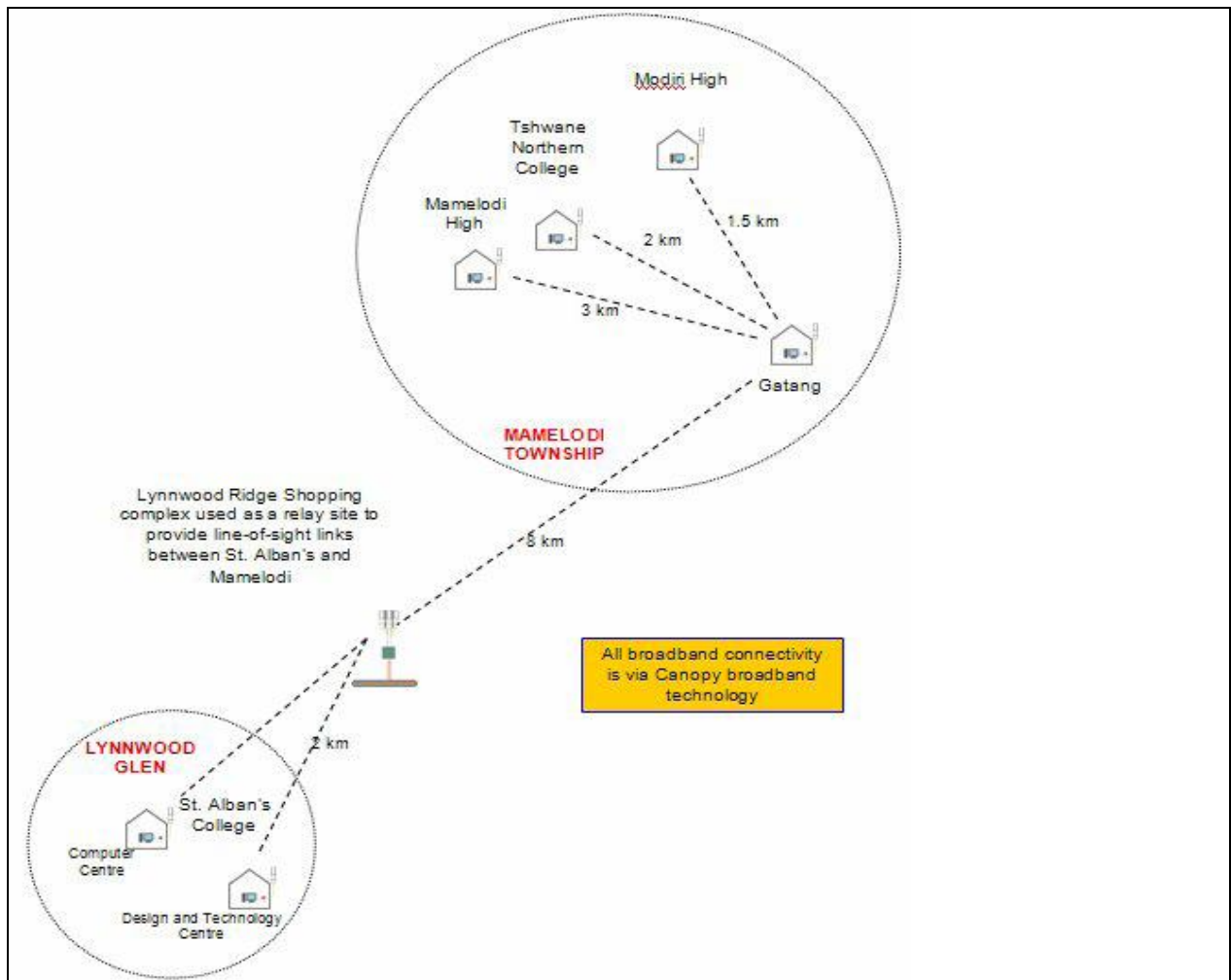


Figure 2.3 Ulwazi project network diagram adapted from (Beyers; 2008)

## 2. 8.2 Tsilitwa Project

The Tsilitwa project is coordinated by the Council for Scientific and Industry Research (CSIR) in the Eastern Cape province of South Africa. The aim of this project is to improve rural health systems. They have deployed a wireless network using 802.11b that covers key centres in Tsilitwa and Sulenkama, as shown in Figure 2.4 (Tsilitwa, 2004; Stockholm, 2004).

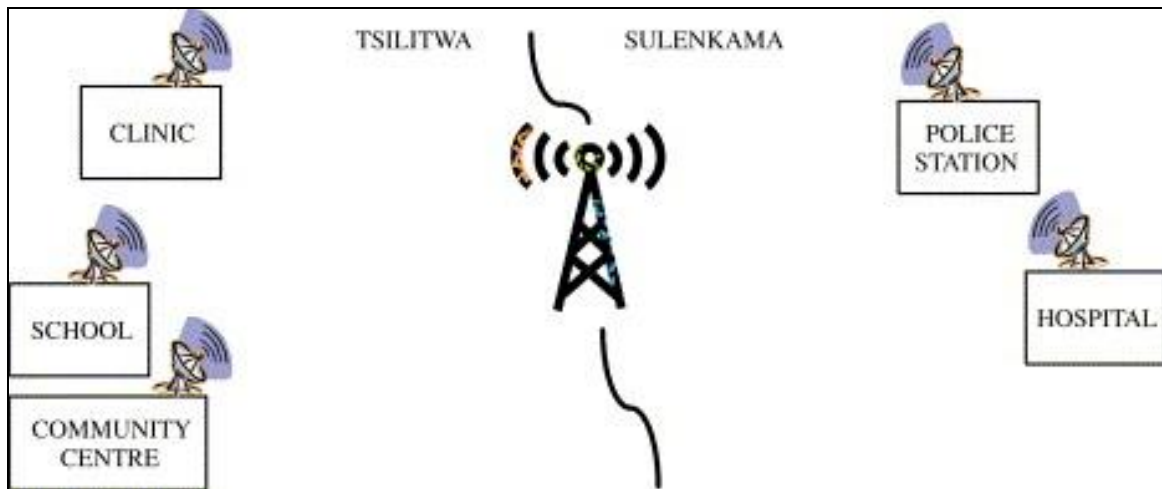


Figure 2.4 Network connectivity within the Tsilitwa project adapted from (Tsilitwa; 2004)

Each facility has an antenna, VoIP and a PC. Between the two villages there is a repeater to boost the signal since there is proper LOS between the two villages (Tsilitwa, 2004; Makan, 2007). The way the network operates is similar to that of the SLL WiMAX network, in that two separate villages are connected wirelessly and each school has its own antenna.

### 2. 8.3 Green Solar Wi-Fi

Green Solar Wireless Fidelity (Wi-Fi), in Haiti, is a non-profit organisation which aims to provide Internet connectivity to the people in marginalised areas through the use of a broadband Internet connection, and solar energy (Bakie *et. al*, 2008). They use Wi-Fi solar access nodes and routers to establish a connection since, in most rural areas, they do not have electricity (Bakie *et. al*, 2008). The use of solar equipment and Wi-Fi can also be a solution to improving the availability of the SLL network.

The Green Solar Wi-Fi hotspot model has a power control device that controls the power usage on the access nodes as well as on the router. This controller has power control module software running on its Wi-Fi router, which communicates through the Ethernet port (Bakie *et. al*, 2008).

### **2. 8.4 Geek Corps**

Geek Corps is another non-profit organization which helps in the building of telecommunication infrastructures in developing countries (Zuckerman, 2009). They achieve this by sending skilled people to marginalised areas. Apart from deploying the networks, the Geek people also offer training to the rural people (Zuckerman, 2009). Their aim is to promote economic growth in the developing world, through the use of ICTs (Pitke, 2007; Zuckerman, 2009).

### **2. 8.5 AirJaldi and Aravind**

Telecommunications networks have been deployed in AirJaldi and Aravind in India, to provide Internet access and VoIP telephony service using a VSAT link in an area covering 70kms radius in India (Surana *et. al*, 2004; Surana *et. al*, 2007).

The Aravind network uses Wi-Fi-based Long Distance Networks (Wild Net) to communicate between the two centers (Surana *et. al*, 2004). These two networks have experienced most of the problems faced by rural networks (Surana *et. al*, 2007). They have overcome some of the challenges by offering training to the people in the community. As a result of this training, the centers are now running with no operational assistance from the people who deployed the network (Surana *et. al*, 2007). These two networks, despite their different locations and applications, have experienced related challenges that have lead to increased downtimes, maintenance costs and power performance of the network (Subramanian *et. al*, 2006).

At first, the network administrators were involved in the planning, design, deployment, and repairs of the networks (Surana *et. al*, 2007). However, eventually they managed to hand over the responsibility of the maintenance of the network to the community, this has led to better performance of the network.

To overcome the problem of monitoring the network, they have designed a Phone Home connection which they installed on their wireless router; this is used to monitor the network remotely (Surana *et. al*, 2007). The routers occasionally post various parameters to their main server website. Server-side daemons examine these data and plot illustration trends (Surana *et. al*, 2007).

The list of the measured parameters is presented to the administrators through graphical means (Surana *et. al*, 2004).

Other telecommunication projects that are done around Africa but are not discussed in this research include (ITNewsAfrica, 2008):

- Voice mail box tele-centers (Maputo);
- Connect rural teachers to their mentors in other provinces (Mozambique);
- Telemedicine and Tele-dermatology (Eastern Cape and Mpumalanga in South Africa);
- Improve education in remote parts of Namibia by providing internet access to schools using Wi-Fi technologies, refurbished PCs and open source software (Namibia).

## **2. 9 Analysis of case studies**

The Ulwazi deployed network is similar to the one on the SLL network where the schools act as the point of contact within the community. This network has mainly experienced cases of equipment failure during the initial stages of deployment. Monitoring problems that occur on the SLL network are still foreign to this network since the administrators stay within the community.

The Tsilitwa network has faced the problem of lack of technical skills amongst the users and has solved this problem by offering training to key people in areas where the network is based. The use of solar equipment can also be a solution to improve the availability of the SLL network although the use of Wi-Fi is not part of this study. This can also be considered a solution, together with the UPS deployed on the SLL network, to make sure that no excess voltage goes to the equipment.

The training offered by Geek Corps is similar to the training sessions offered by the Siyakhula Living Lab project; experts go down to the network site and offer training to people in the community. This will help the performance of the network since the users will be technically skilled in working on the network.

The AirJaldi and Aravind networks aim to empower the rural people and this is also one of the goals for the SLL project, i.e. to ensure the empowerment of the local people (Siyakhula

Project, 2007). These two networks also use automatic monitoring systems which could be used on the SLL network. Most of the solutions implemented on these networks will also be implemented on the SLL network.

## **2. 10 Conclusion**

This chapter has provided information on the existing rural networks, in particular those deployed in South Africa. Detailed information on how rural communities are setup and how they handle their network problems, together with an analysis of different case studies, was also covered in this chapter. The next chapter discusses the access technologies that have been deployed on the SLL network and other possible technologies that can be introduced to improve its resilience against failure.

## **Chapter Three: Network technologies and the deployed network**

### **3.1 Introduction**

This chapter discusses network technologies, other monitoring systems and backup systems that can be used on the network. These technologies have been used on other telecommunication networks. The chapter further explores specific access technologies that are already deployed on the SLL network, and their categories.

### **3.2 Network technologies**

These are different types of technologies that are currently being used on telecommunication networks, some of these include Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Metropolitan Area Network (MAN), Satellites and Cellular access technologies. Some of the technologies mentioned above are already used within the SLL community as shown in the network diagram shown in Figure 1.1. Factors such as cost of deployment, compatibility with other technologies as well as ease of equipment availability determines the choice of these technologies.

#### **3.2.1 Bluetooth**

Bluetooth is a WPAN technology which enables wireless communication between mobile devices that are centred in a single area. Compared to Infra-Red (IR), Bluetooth does not require a line of sight between devices for it to work. It is able to communicate through physical barriers, typically with a range of 10 meters, although it can stretch up to 100 meters when power amplifiers are used (Salmi, 2006). Bluetooth uses the unlicensed 2.4-GHz spectrum for communication, with a peak throughput of 720 Kbps. It is expected that this throughput will increase to around 10 Mbps with future Bluetooth specifications (Salmi, 2006, Disqus, 2009). Bluetooth is commonly used for sharing music, photos and other files that can be handled by modern mobile devices. Even people in Dwesa make use of this technology since it is already available on their cell phones and it is easy to use.

### **3.2.2 General Packet Radio Service (GPRS)**

The other network technology is General Packet Radio Service (GPRS) which is a cellular access technology. GPRS is a packet data communication system which is integrated with the GSM cellular telephone system (Mahdi, 2004). GPRS is a large, complex system that combines cellular, telephone radio transmission technology and Internet information delivery protocols. Initial implementations of GPRS operated within the framework of present GSM technology (Mahdi, 2004; Michael, 2006).

The use of GPRS has made several devices deployable since it turned out to be compatible with other equipment that was not compatible with traditional GSM networks, due to its limits in speed, message length of the Short Message Service (SMS), dial up time and costs (Mahdi, 2004).

In South Africa, GPRS network service providers are MTN, Vodacom, Cell C, Virgin Mobile and 8ta. These service providers currently also offer other services such as Enhanced Data for GSM Evolution (EDGE), Third Generation (3G) and High-Speed Data Packet Access (HSDPA). Cell C and 8ta have the best internet deals at the moment. For Cell C you get the following summarised prepaid package deals (MyBroadband; 2011):

- For R1, 499 a year, users get a modem capable of speeds of up to 7.2Mbps and 2GB of data every month for a period of 12 months;
- For R2, 999 a year, users get a modem capable of speeds of up to 21.6Mbps and 5GB of data every month for a period of 12 months.

There are various efforts by other service providers in South Africa to provide GPRS and related standards so as to provide data at cheaper rates. Below are tables showing the different costs of data for each of these networks:



Table 3.1: 8ta GPRS data bundles

Once off bundle	Bundle cost	Price per MB in bundle	Price per MB out bundle
100MB	R50.00	R0.50	R1.00
250MB	R100.00	R 0.40	R1.00
500MB	R150.00	R0.30	R1.00
1Gig	R250.00	R0.24	R1.00

Table 3.2: Vodacom GPRS data bundles

Once off bundle	Bundle cost	Price per MB in bundle	Price per MB out bundle
0MB	R0.00	R2.00	R2.00
20MB	R35.00	R1.75	R2.00
75MB	R110.00	R1.47	R2.00
150MB	R149.00	R0.99	R2.00
250MB	R200.00	R0.88	R2.00
500MB	R350.00	R0.70	R2.00
1000MB	R599.00	R0.60	R2.00
2000MB	R1198.00	R0.60	R2.00

Table 3.3: MTN GPRS data bundles

Once off bundle	Bundle cost	Price per MB in bundle	Price per MB out bundle
0MB	R0.00	R2.00	R2.00
10MB	R10.00	R1.00	R2.00
100MB	R100.00	R1.00	R1.50
350MB	R220.00	R0.63	R1.50
1024MB	R499.00	R0.49	R1.25

<sup>1</sup> Table 3.4: Cell C data bundles

Tariff option	Tariff cost	10MB	20MB	50MB	100MB	200MB	500MB	1024MB
Smart data standard	R0.00	R20.00	R40.00	R100.00	R200.00	R400.00	R1000.00	R2048.00
Smart data personal	R15.00	R32.50	R50.00	R102.50	R190.00	R365.00	R890.00	R1807.00
Smart data professional	R60.00	R75.50	R91.00	R137.50	R215.00	R370.00	R835.00	R1647.20

The reduction in MTN internet tariffs, to 25 cents per megabyte, and the introduction of the Cell C 3G card where you pay R3000 per annum and get 5 Gigabytes per month as well as the different bundle costs from Vodacom have made GPRS and 3G technologies more affordable. These technologies enable Internet access to all mobile subscribers (MTN South Africa, 2010, Cell C South Africa, 2010, Vodacom South Africa, 2010). GPRS is a technology that can be used for Internet access where there is coverage (Madhi, 2004). Apart from the affordability of GPRS a major drawback to the use of this technology, especially in rural areas, is the type of cell phones that people in these areas use (Chauville *et al*, 2007).

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<sup>1</sup> The term bundle refers to the amount of data that is used to download information and its standard unit is MB. Out-of-bundle refers to the amount a user is charged when the data bundles they have bought are depleted.

### Advantages of GPRS:

- A GPRS enabled device breaks information down into "packets" and sends it over multiple channels (Michael, 2006). Every packet takes the shortest available route to the recipient, where it is built into the original message (Michael, 2006). This increases the speed of transmission and reduces signal errors;
- GPRS networks do not include deployment costs since they are highly mobile and users do not need to put up any form of permanent infrastructure (Mahdi, 2004);
- With GPRS, users can stay permanently connected to the mobile Internet without incurring any costs (Michael, 2006). This is because, with GPRS, users are only charged for the amount of information they send and receive, and not the amount of time spent connected (Mahdi, 2004).

### Disadvantages of GPRS

- GPRS can only be used in areas where there is GPRS network coverage. If the GPRS network is far from the nearest GSM cell tower, the connection speed is reduced (Jeremy, 2004);

## 3.3 Access technologies already deployed on the SLL network

All the access technologies discussed above have not been deployed on the SLL network. The SLL network uses VSAT and WiMAX as its access technologies. These two technologies were used on this network because they catered for most of the requirements of the SLL project (Mandioma *et. al.*, 2007). Below is a discussion of these two technologies and some of the features that made them suitable as primary technologies for the SLL network.

### 3.3.1 VSAT

As described in Chapter 1, VSAT is our primary technology that establishes the connection with our service provider on the SLL network, as shown in Figure 3.1 (Mandioma, 2007). VSAT is the name given to a small earth-fixed earth station which is usually 0.75 to 2.4m in radius. This small earth station is used to provide connectivity on satellite based communication networks (Maral, 2003). The VSAT station is comprised of two separate sets of equipment, namely the OutDoor Unit (ODU) and the Indoor Unit (IDU) (Pagarkar, 2006).

“The outdoor unit is the VSAT interface to the satellite, while the IDU is the interface to the customer’s terminal or LAN” (Maral, 2003).

The VSAT technology is used as a cost-effective solution for users looking for an independent communication network platform that connects to sites located on different locations (Jauhari, 2008). VSAT can also be used in telecommunication applications such as Internet/Intranet access, corporate networks, rural telecoms, environmental monitoring, E-learning, telemedicine and various other applications (Pagarkar, 2006).



*Figure 3.1: VSAT deployed at Mpume*

Table 3.5 shows some of the prices for deploying and using the Telkom VSAT in South Africa. The SLL network has a download speed of 512 Kbps and 128 Kbps upload, and a monthly volume cap of 3Gbytes. On the SLL, the Telkom Internet Powered by Satellite (TIPS) is used because people cannot access the web via traditional phone lines in this area (Telkom South Africa, 2009).

Table 3.5: Telkom VSAT pricelist adapted from Telkom SA

Item A1.4.13	SpaceStream Express (SSE) (Option 1 - Installation charge paid up-front)	Activation/Installation(Rand)		Monthly rental (Rand)	
		Excl VAT	Incl VAT	Excl VAT	Incl VAT
a	SpaceStream Express				
(i)	64 K/bits - Includes data volume cap of 500 MB:				
	-1 Year contract	2 719.30	3 100.00	495.80	565.21
	-2 Year contract	2 719.30	3 100.00	481.57	548.99
	-3 Year contract	2 719.30	3 100.00	470.62	536.51
(ii)	128 K/bits - Includes data volume cap of 1000 MB				
	-1 Year contract	2 719.30	3 100.00	623.51	710.80
	-2 Year contract	2 719.30	3 100.00	606.88	691.84
	-3 Year contract	2 719.30	3 100.00	591.59	674.41
(iii)	256 K/bits - Includes data volume cap of 2000 MB				
	-1 Year contract	2 719.30	3 100.00	879.05	1 002.12
	-2 Year contract	2 719.30	3 100.00	857.02	977.00
	-3 Year contract	2 719.30	3 100.00	833.53	950.23
(iv)	512 K/bits - Includes data volume cap of 3000 MB				
	-1 Year contract	2 719.30	3 100.00	1 134.54	1 293.38
	-2 Year contract	2 719.30	3 100.00	1 107.95	1 263.06
	-3 Year contract	2 719.30	3 100.00	1 075.47	1 226.04
	Additional data volume per 1000 MB increment on the 512 kbps service only* <b>Note 16l</b>	-	-	417.44	475.88
b	indoor transfer of VSAT, per access	1500.00	1710.00	-	-

#### Advantages of VSAT technology

- Networks that are deployed using VSAT technology are sustainable and manageable since it is easy to add new devices to the network as well as moving the station to a new site (Baghaei, 2004; Yahya, 2009);
- The monthly payments for VSAT networks are usually fixed as well as the bandwidth on the network. This also makes the cost of running a VSAT network easy to estimate (Yahya, 2009);
- The equipment required to setup a VSAT network is usually located in one area which makes it easier to maintain the network and detect faults if anything happens to the unit itself or the ODU or the IDU (Yahya, 2009).

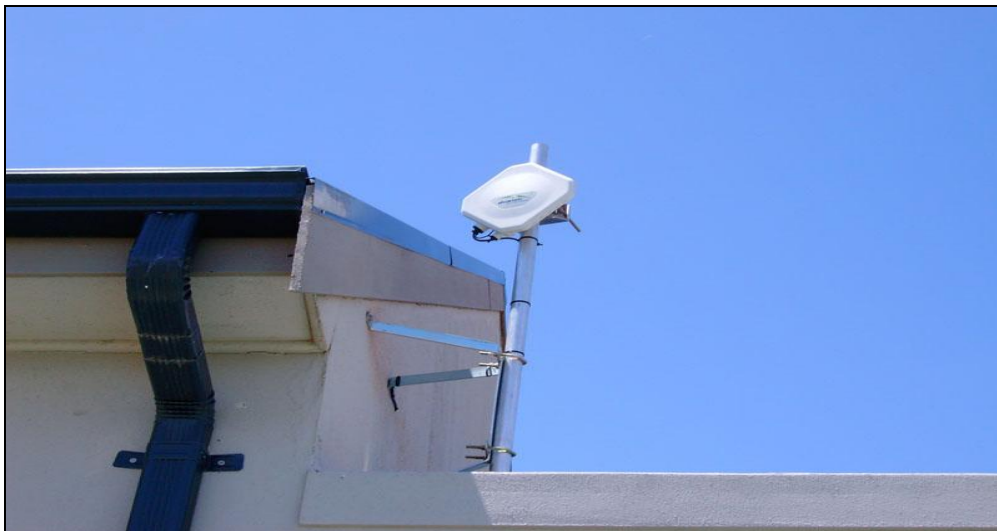
#### Disadvantages of VSAT technology

- The cost of buying and deploying all the equipment can be very expensive since, in most cases, the equipment is put up at the same time (Gumatse, 2004);
- Latency can impact some application performance, thus resulting in delays (Focus Group, 2006);

- Requires a clear line of sight between a dish and satellite (Focus Group, 2006)
- Dish installation and setup of the whole network usually takes time since the setting up of the whole network requires expert skills from the service providers who usually take time in responding to installation applications (Gumatse, 2004).

### 3.3.2 WiMAX

WiMAX is a metropolitan area network (WMAN) technology that interconnects a number of local area networks (LANs) using a high-capacity backbone technology, such as fibre-optical links, and provides up-link services to wide area networks (WAN) and the Internet (Laudon,2009).



*Figure 3.1: Picture of the WiMAX deployed at SLL network (Ngwane)*

WiMAX is a technology that is, in most cases, used to establish backhaul connectivity over long distances (Forsman, 2005). It is used in rural areas where setting up the necessary infrastructure on a single connection can be hindered by distance and other natural obstacles, since it does not always require LOS to establish a connection (Behmann, 2006; Breeding, 2002). A WiMAX can cover up to about 50 kms radius with a bandwidth of up to 70Mbps (Broadband Wireless, 2007; Kazzit, 2008). Despite WiMAX having a long range, the longer the range the weaker the signals become because signal strength decreases as distance increases. Alternatively, trees and buildings also contribute to signal degradation (Sweeny, 2004). WiMAX technology has gone through numerous generations since its beginning in 1997. Some of the standards are:

## **802.16**

This was the first version of the WiMAX standard which has a range above 10 GHz and supports line of sight (Providing Complete Solution, 2008). On this standard, the orthogonal frequency division multiplexing (OFDM) technique was addressed (Providing Complete Solution, 2008).

### **802.16a**

The 802.16a standard incorporated non-line-of-sight (NLOS) and its spectrum range can go up to 11GHz (Hoskins, 2008). “This version enhanced the medium access control (MAC) layer capabilities. This version was the first to support both time division duplexing (TDD) and frequency division duplexing (FDD)” (Hoskins, 2008; Providing Complete Solution, 2008).

### **802.16d**

This standard is an improvement on previous sessions. Some of the enhancements included support for concatenation of both protocol data units (PDU) and service data units (SDU) which, as a result, reduced the MAC overhead (Kazzit, 2008)

## Advantages of WiMAX

- WiMAX is a WAN technology that can provide up to 50 km coverage with a throughput of 70 Mbps, making it a possible solution for rural connectivity (Wei *et. al*, 2005);
- The deployment of a WiMAX network is easier compared to that of VSAT (Focus Group, 2006);
- It is standardized; as a result, it can be easily integrated into other networks;
- It opens up a completely new access alternatives to bring broadband access to the business community in urban areas (Intel, 2005);
- WiMAX can also be used to access the Internet through the use of hot spots and provides a wireless network extension to cable. There is no need for the tower to achieve long coverage (Wei *et. al*, 2005; Intel, 2005).

## Disadvantages of WiMAX

- The signal transmission of WiMAX can be affected by bad weather conditions (Kuttra, 2006);
- Without LOS backhaul, connectivity is not possible for long distances (Kuttra, 2006);
- In South Africa, at present very few companies offer WiMAX products. Consequently, equipment is shipped from other countries which makes it more expensive than it would be if manufactured locally (Kuttra, 2006);
- WiMAX equipment is power intensive and requires strong electrical support (Kuttra, 2006).

### 3.3.3 Wi-Fi

The Connection of computers and other equipment without the cost and complexity of cabling has increased the use of wireless technologies, in particular the Wi-Fi market, over the past years (Onno, 2007). Wi-Fi is an example of a WLAN which allows two or more devices to be linked using wireless distribution methods such as spread-spectrum or OFDM radio, and usually provides a connection through an access point to the wider internet. Wi-Fi has gone through different stages from 1997 up to now (Bradley, 2005). This technology has been deployed on the SLL network as of October 2010. The continuous changes in different Wi-Fi standards were a result of improvements in the Wi-Fi technology (Baghaei, 2004; Bradley, 2005). Table 3.1 shows a summary of the different Wi-Fi standards 2009:



Table 3.6: Wi-Fi standards

<b>802.11</b>	The original WLAN standard; It supports 1 to 2 Mbps.
<b>802.11a</b>	High-speed WLAN standard for 5 GHz band; supports 54 Mbps.
<b>802.11b</b>	WLAN standard for 2.4 GHz band; supports 11 Mbps.
<b>802.11d</b>	International roaming: automatically configures devices to meet local RF regulations.
<b>802.11e</b>	Addresses quality-of-service requirements for all IEEE WLAN radio interfaces.
<b>802.11f</b>	Defines inter-access-point communications to facilitate multiple-vendor-distributed WLAN networks.
<b>802.11g</b>	Establishes an additional modulation technique for the 2.4 GHz band; supports speeds up to 54 Mbps.
<b>802.11h</b>	Defines the spectrum management of the 5GHz band.
<b>802.11i</b>	Addresses the current security weaknesses for both authentication and encryption protocols; the standard encompasses 802.1X, TKIP, and AES protocols.
<b>802.11n</b>	Provides higher throughput improvements; intended to provide speeds up to 500 Mbps.

#### Advantages of Wi-Fi

- Wi-Fi has a set of standards allowing interoperability between different types of access points and client network interfaces, at a basic level of service (Gumatse, 2004). As a result, the deployment Wi-Fi networks are cost effective and easy to deploy;
- The absence of cables means that there are no cabling costs incurred. The infrastructural cost of deployment of wired connectivity is usually high and the outcome from the network, in terms of revenue, is low in addition, wireless has been the best solution since there are no cabling costs (Gumatse, 2004). This is mostly the case with connectivity in disadvantaged, rural areas;

- Wi-Fi products are widely available in the market unlike WiMAX equipment which has to be ordered from overseas (bwif.org, 2006).

#### Disadvantages of Wi-Fi

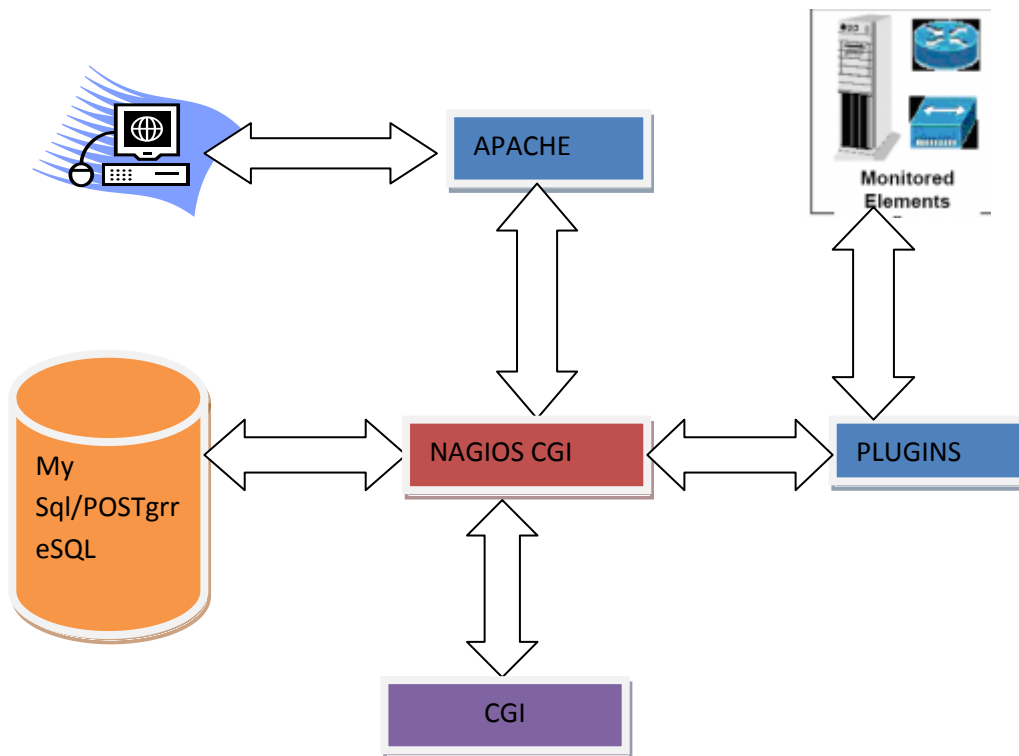
- Access points can be used to steal personal and confidential information transmitted from Wi-Fi consumers ( Jones,2002)
- Wi-Fi has a short network coverage compared to WiMAX (bwif.org, 2006).

### 3.4 Remote network monitoring systems

There are several network technologies that can be used. However, the use of these different technologies does not mean that the network is perfect or error free. Network problems occur due to the disadvantages of access technologies, but some of the problems that occur are a result of lack of monitoring. The section below discusses some of the network monitoring tools that have been used on other networks. The importance of having network monitoring systems is to check the network and send feedback to the administrators. Therefore, monitoring systems act as the administrator's eyes on the network.

#### 3.3.1 Nagios

Nagios is a system and network monitoring application (Karmic *et al*, 2008). Nagios only monitors and sends alerts on the functionality of services such as the protocol in use, disk usage and connectivity of servers at Mpume and Ngwane (Karmic *et al*, 2008). Nagios works with a set of plugins that provide local and remote service information. The monitoring daemon on Nagios runs regular checks on the hosts and services specified (Karmic *et al*, 2008). When a failure is detected on the network, the daemon sends notifications out to administrative contacts in different ways such as email, instant messaging and sms, as can be done on Zenoss (Navies Enterprise, 2009). Nagios also supports the implementation of redundant hosts (Galstad, 2008). Figure 3.3 below shows the architecture of Nagios. Below is the architecture diagram of the Nagios architecture.



*Figure 3.3: Internal architecture of Nagios*

#### Advantages of Nagios

- It is an easy-to-use product, which has all the functions needed to perform availability monitoring built into it (Galstad, 2008);
- Extensions (plug-ins) are simple to develop, using well known languages. With Nagios, administrators can add other php scripts so as to fit their particular needs (Navies Enterprise, 2009);
- It is scalable, and it is possible to deploy a hierarchy of Nagios servers to provide consolidated views of network and / or system availability (Galstad, 2008).

#### Disadvantages of Nagios

- It is difficult to add machines to be hosted on the monitoring system;
- There is a need to always keep track of the available upgrades and updates since Nagios does not update itself automatically (Navies Enterprise, 2009).

### **3.3.2 Cacti**

Cacti is an extensible network monitoring package. It is comprised of tools such as Multi Router Traffic Grapher (MRTG) and Round Robin Database (RRD) Tools (Schwartz, 2008). It further provides fast polar, advanced graph templating, multiple data collection methods, and user management features, out of the box. All of this is combined in an easy-to-use interface that can be used on small and big LANs (Schwartz, 2008; Tsapskin2008).

#### **Advantages of Cacti**

- Cacti provides fast polar advanced graph templates. It can be used to check on any activity on the network (Schwartz, 2008);
- It does not use many resources on the host machine, one only needs to install PHP for it to work on your machine (Nag, 2008);
- More than one user can be given administrator privileges (Schwartz, 2008).

#### **Disadvantages of Cacti**

- Cacti templates are laborious to create, they take a long time and are error- prone (Nag, 2008);
- Cacti data models are complex to understand for first time users (Nag, 2008).

There are also different technologies developed for network backups, as will be discussed in the section below.

### **3.5 Configuration Backup Systems**

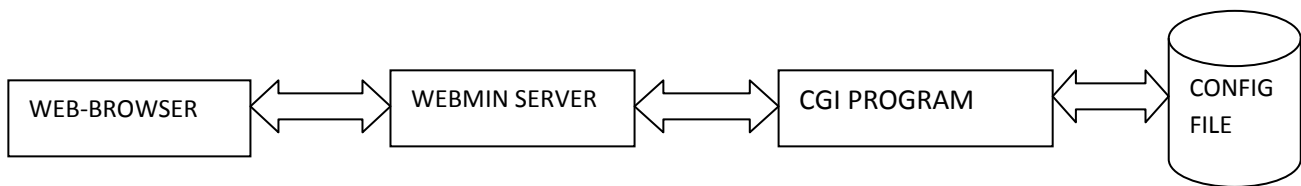
As highlighted earlier in the chapter, telecommunication networks need to be constantly monitored. Monitoring alone does not solve all the problems that a network is likely to face. To increase availability on the network, there is a need to have a copy of the critical configurations stored somewhere so that administrators can refer to and use these configurations in the event of failure of the originals. Below are some of the configuration backup systems that have been used on other telecommunication networks.

### 3.5.1 Simple Backup Suite

Simple Backup Suite (sbackup) is a simple backup solution (Kane, 2008). It can be used to create copies of a subset of files and directories. When using sbackup, backups can be saved on any local and remote directories that are compatible with gnome-vfs (Kane, 2008). Sbackup has a GUI that shows the location of the backed up files (Kane, 2008).

### 3.5.2. Webmin

Webmin is a web-based interface that can be used on UNIX and Linux systems (Cameron, 2007). When using Webmin, there is no need to manually edit configuration files such as /etc/passwd (Cameron, 2007). Webmin is written using Perl, and it runs as its own process and web server. The Webmin interface can be used on any interface and can be developed without problems. It can be accessed even if you are not on the network (Cameron, 2007).



*Figure 3.4: Architecture of Webmin adapted from (Cameron, 2007)*

Functions that deal with the actual configuration files, converting them to and from data structures used by the actual programs are contained in the CGI program (Cameron, 2007). There is a layer of abstraction between the CGI programs and the system, although this abstraction is not enforced and is by-passed in some cases (Cameron, 2007; Kane, 2008). The technologies discussed in the above sections are possible solutions for the SLL network, but have not yet been deployed.

## 3.6 Conclusion

Identifying various network technologies has helped us perform an in-depth analysis of the current technologies. From this discussion we managed to select the most suitable technologies that can be used as solutions on the SLL network. The results obtained from implementing these technologies are discussed in Chapter 5 of this study. Apart from the already deployed technologies (WiMAX, Wi-Fi and VSAT), this research seeks to introduce

GPRS as a redundant link to the VSAT network. For monitoring, we have used Nagios and Cacti and for backup we have used the Simple Backup Suite. The proposed technologies are discussed in detail in the ensuing chapters. The next chapter discusses the various problems that have been experienced on the SLL deployed network and the solutions that have been implemented on the network.

## **Chapter Four: SLL network problems and solutions**

### **4.1 Introduction**

Common network problems experienced in marginalised areas have been highlighted in Chapter 2. This chapter focuses on the network problems that have been experienced by the SLL network, over the past two years, after the deployment of the network and the solutions that we have implemented. We collected the list of problems throughout the research and classified these problems according to the degree of difficulty in solving them, their type (hardware, software, social and environmental conditions) as well as the effect they had on the network.

### **4.2 Actual problems on SLL network**

The problems on the SLL network were logged for the two years in which the research was carried out. Below is a summary of problems that were frequently experienced during this period. A full list of all the problems experienced on the network is provided in *Appendix 1*.

#### **Administration problems**

- Administrators stay far away from the network site. They only visit the site once a month. In some cases, when they visit the network they realise that there are problems that have occurred that they were not aware of and thus do not have enough equipment to solve them.

#### **Lack of skills and knowledge**

- The teachers in charge of the network at the schools are sometimes unable to fully understand the SLL network architecture;
- On one occasion the users at Mtokwane, Nondobo and Ngwane spent days without internet connection because the access concentrator at Mpume was not booting properly. When the administrators got to the site they realised the keyboard was not plugged in and, as a result, the access concentrator's boot sequence was freezing at the "hardware check" stage;

- The schools on the SLL network have spent days without internet connection because the teachers at Mpume, the school where the VSAT is located, had switched off the server and access concentrator as a way of saving electricity;
- The network users sometimes try to solve problems that they are not sure of and, in the process, damage more equipment or change critical configurations on the servers and routers;
- The teachers responsible for the network are sometimes unable to precisely report the network problems in detail. In most cases, the users give reports such as “the internet is down” without specifying the actual problem. In other cases, they just say the “monitor is sleeping” referring to a computer not switching on.

### **Broken equipment**

- The connection to the internet has been lost because the VSAT’s outdoor unit (ODU) was not working properly or it was broken;
- In some cases the connection was lost due to key equipment on the network, such as the micro base station, router and other components of the computers being broken.

### **Harsh environmental conditions**

- On one occasion the micro base station at Ngwane and other network equipment was damaged by lightning.

## **4.3 Summary of problem categories**

Below are tables that summarise the different network problems that are experienced on the SLL network. The detailed table is shown in *Appendix 1*. The tables are categorised in terms of the type of problems, which are: hardware, software, social and environmental problems. In each table the problems are further divided in terms of their nature. Under the nature of problems we have the following categories based on the view of the administrator:

<i>Easy</i>	These are problems where users needed little or no assistance at all from the network administrators.
<i>Medium</i>	The users needed help in solving the problems but most of the problems under this category can be remotely solved.



*Difficult* These problems required a visit to the network site by the network administrators or service providers.

There are two categorises for the types of problems, and these are:

*Technical* These are problems that need technical know-how.

*Non-technical* These are problems that require little or no knowledge of telecommunication networks.

*Variable X* Indicates the different categories in which the stated problem falls.

The categories mentioned above include unreliable network services and unpredictable network problems.

### **Hardware and Software problems**

These are problems that are primarily caused by equipment failure. Table 4.1 shows the problems that are in this category.

Software problems are those problems that are experienced as a result of corrupt configurations and other program failures.

The problem of not having the link between the schools is listed twice in table 4.1 (as loss of signal and no link). This is because the loss of communication between the schools can be caused by equipment that is not working, or is broken, or by the people deliberately switching the equipment off.

Table 4.1: List of hardware and software problems on SLL network

Problem	Nature of problem			Category of problem		Frequency of occurrence	
	Easy	Medium	Difficult	Technical	Non-technical	more than once	only once
Faulty VSAT ODU antenna			X	X			X
Router intentionally switched off	X				X	X	
Users at Ngwane not able to access or open the web browser	X				X	X	
Router not booting at Ngwane		X			X	X	
Server freezing at Ngwane		X		X		X	
Broken equipment at Ngwane	X				X	X	
No link between Mpume and Ngwane		X	X			X	
Router crashing			X	X		X	
Backdoor not connecting to the network			X	X		X	
Monitors at Ngwane automatically going into safe mode		X		X			X
Mpume server not booting because it was full		X		X			X
UPS not charging and beeping		X			X		X

### **Social and organisational problems**

These are problems that are primarily caused by the users. Table 4.2 shows some of the problems that are listed under this section.

Table 4.2: List of social problems on SLL network

Problem	Nature of problem			Category of problem	
	Easy	Medium	Difficult	Technical	Non-technical
Shortage of data bundles on the entire network	X				X
Deliberate switching off of equipment at Mpume	X				X
Lack of technical skills in the community		X			X
Abuse of network equipment on the network	X				X
Limited security on infrastructure at the schools		X			X

### Environmental problems

These are problems that occur due to harsh weather conditions, such as lightning. Table 4.3 shows some of the problems that are listed under this section.

Table 4.3: List of Environmental problems on SLL network

Problem	Nature of problem			Category of problem	
	Easy	Medium	Difficult	Technical	Non-technical
Micro-base station struck by lightning			X	X	
Power failures caused by bad weather	X				X

### 4.4 Summary of the problems

After observing the problems as they occurred on the network we realised that the main problem faced by the SLL network is unavailability of the network and its services. This is a

result of unreliable network services and unpredictable network failures. Another problem on the network is that administrators are located far away from the site and they cannot keep an eye on the day-to-day activities of the network. This lack of monitoring led to different levels of network problems ranging from the technical to non-technical (Ranga *et.al*, 2008). This greatly increased the down time of the network since administrators only get to know about the problems when they visit; in most cases they have to take the damaged equipment with them to the universities since they will not have carried enough resources to fix it from the SLL network site. Besides the monitoring problems, this network lacks backup systems that are readily available when the primary systems stop working.

We appreciate the fact that networks are affected by different problems. Previous chapters have provided details concerning these problems. However, we have identified the actual network problems affecting the SLL network. The next section discusses solutions that have been implemented on the network to solve the problems that are currently being experienced on the SLL network.

#### **4.5 Description of solutions implemented on the SLL network**

There are various network problems that are experienced on the SLL network. In this section we explain in detail the problems summarised in the previous section and we discuss feasible solutions that were implemented on SLL network.

##### ***Problem***

*Inadequate network knowledge-* The project champions and users have inadequate knowledge and training on the architecture of the network. This sometimes results in damage to the network when users try to solve network problems that they are not well versed in.

##### ***Solution***

As a way of trying to educate the users, we conducted training sessions with the teachers, students and people from the community. As part of the training, we took time in explaining the network architecture and illustrated how the schools are linked. A poster was designed, as shown in *Appendix 3*, to show the users how the hardware components are connected to the system unit. A brief tutorial on the key configurations that should be checked if connection is lost was compiled, and is shown in *Appendix 4*. These users were trained on different courses,

i.e. introduction to computing and basic computer concepts as well as basic network trouble shooting and the Pre Ace course. At each school SLL project, champions have been nominated and are equipped with extra technical training to improve network fault diagnosis. The administrators communicate with these project champions and people in charge of the networks at the schools of any changes that they make on the network.

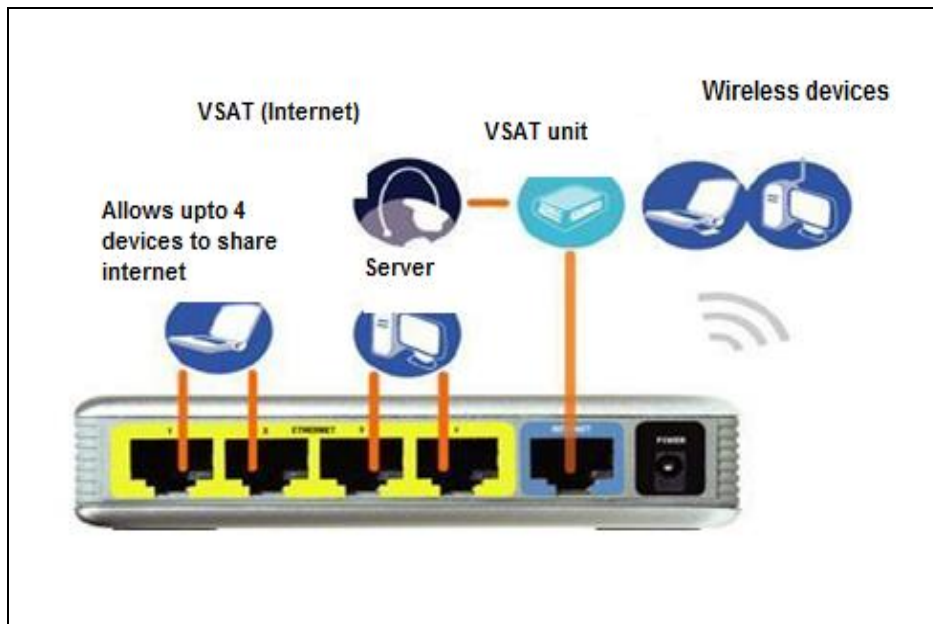
### ***Problem***

*No internet-* Loss of internet connectivity caused by no internet connection from the VSAT unit.

### ***Solution***

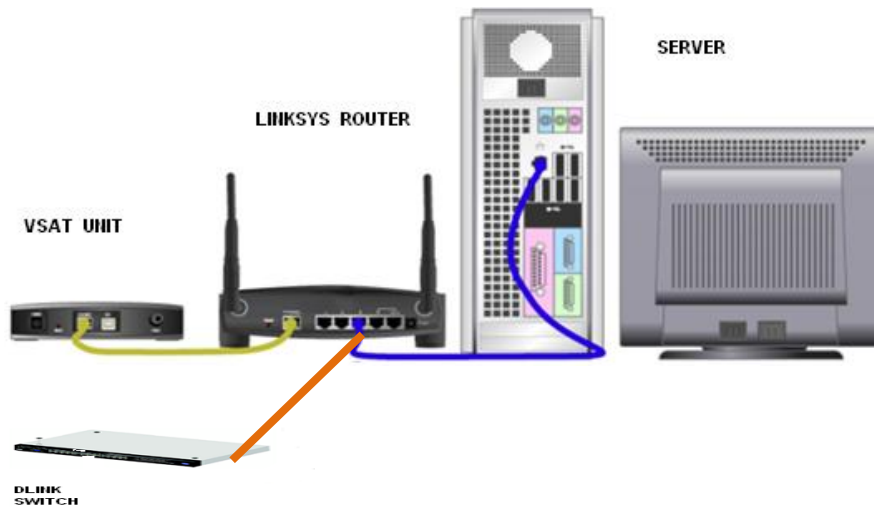
To improve the availability of connectivity at all times we have introduced GPRS internet using a Linksys router to act as a backup redundant link for the VSAT link so that the users remain connected even when the internet provided by the VSAT is down.

The Linksys router is directly connected to the indoor VSAT unit on the port labelled Internet. The router is also connected to the Mpume server on the port labelled Ethernet, as shown in Figure 4.1. On the same network, the Mpume server is then connected to the switch which then connects all the other clients on the network, as shown in Figure 4.2.



*Figure: 4.1: Back view of the Linksys router*

Figure 4.2 shows the physical layout of how the Linksys router was connected onto the SLL. Initially the VSAT unit was plugged directly into the server at Mpume. After the deployment of the Linksys router, the VSAT unit is now plugged into the Internet port on the router while the server and the switch are plugged into the Ethernet ports. These new connections and configurations enable the network to automatically switch over to the GPRS link if there is no traffic received from the VSAT link.



*Figure 4.2: Physical layout of the Linksys SLL network*

In order to make sure that the Linksys router acts as a redundant link and smoothly fits into the already deployed network key configurations were made on the router, such as:

- The interface that connects to the VSAT interface (Internet) was assigned IP addresses 10.15.0.1;
- We disabled the DHCP functionality on the router so that the standard DHCP on the server continues assigning the IP address on the network.

The VSAT link automatically switches to the GPRS link on the Linksys router as soon as it notices that there are no packets being received from the VSAT link. Several tests were done to make sure that the switching is constant and the GPRS goes back on standby as soon as the network starts receiving packets from the VSAT link. We used GPRS because no costs are incurred when it is on standby. When using the GPRS link, files that use a lot of bandwidth through downloads and uploads, such as Youtube, face book and all ftp sites, were blocked as a way of reducing cost. The results obtained from the redundant link are discussed in Chapter 5.

### ***Problem***

*Poor communication between users and administrators-* Administrators rely on emails and phone calls from the users on the site, if there is a problem on the site. Unfortunately, this



does not fully prepare the administrators for the problems when they go to the network site. Therefore, the administrators have to travel to the site to diagnose the problems and, in some cases, they will not be prepared to solve the problem.

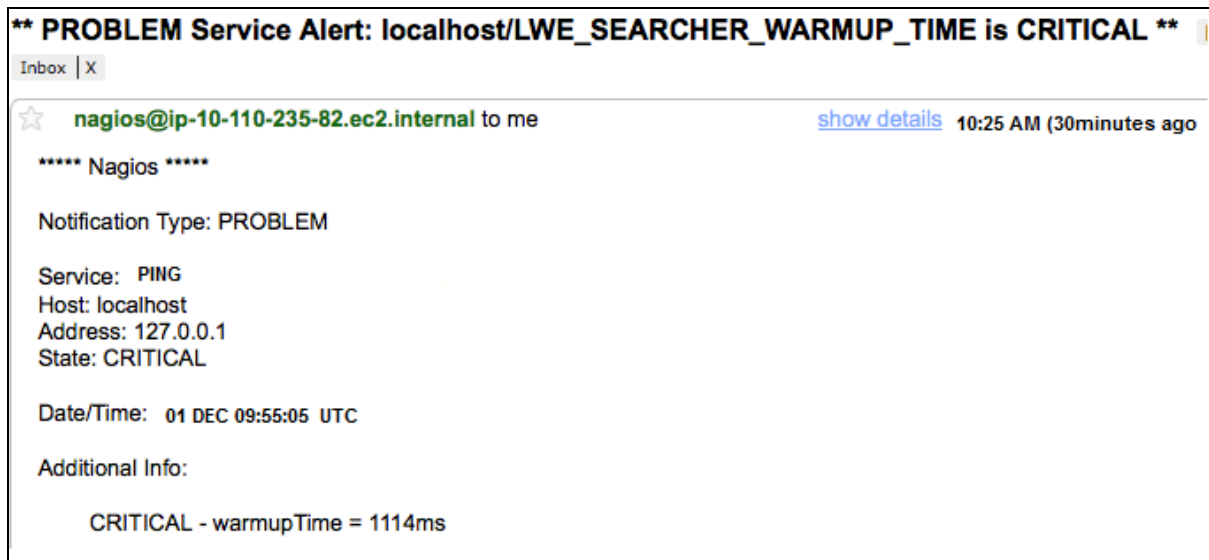
### ***Solution***

To overcome this problem we have deployed a monitoring system called Nagios. It is a network monitoring application that only monitors and sends alerts on the hosts and services that have been specified by the administrator. The allowed METRIC STATUS are 0 (OK), 1 (WARNING), 2 (CRITICAL) or 3 (UNKNOWN). If the network is down and the status of the services monitored moves from being OK to CRITICAL, an email is sent to the administrator. Also, the teachers in charge can log onto the interface of Nagios to check the status of the services.

Configuration segment 4.4 below gives the details of the administrator and the period of time when notifications can be sent to their emails. The sending of emails is a key feature in the monitoring system since, as mentioned earlier, the administrators are located away from the site and, as a result, they get some of the feedback through the emails.

```
Define contact {  
    Contact_name           memory  
    alias                  memory  
    service_notification_period workhthes  
    host_notification_period 24x7  
  
    service_notification_commands notify-service-by-email  
    host_notification_commands  notify-host-by-email  
    email                  mranga@ufh.ac.za  
}
```

*Configuration segment 4.1: Administrator's contact details*



*Figure 4.3: Screenshot of email sent to administrator*

Configuration segments 4.2 and 4.3 show how the hosts were added to the Nagios server. We installed this monitoring system on the servers at Mpume and Ngwane because these are the key schools on our network (Mpume: School with the VSAT and Ngwane: School with the WiMAX base station).

```
define host{
    use                Linux-server
    contact_groups     Dwesaadmins
    host_name          Mpume server
    alias              Mpume
    address            192.168.0.1
}
```

*Configuration segment 4.2: Adding Mpume server to the system*

```
define host{
    use                Linux-server2
    contact_groups     Dwesaadmins
    host_name          Ngwane
    alias              Ngwane
    address            192.168.0.2
}
```

*Configuration segment 4.3: Adding Ngwane server to the system*

```

define service{
    use                basic-service
    hostgroup_name     sles-servers,media-servers
    service_description PING
    check_command       check_ping!100%.0, 0%. 100
}

```

#### *Configuration segment 4.4: Command to check for connectivity using ping*

Configuration segment 4.4 monitors the connectivity fixed between the two servers where Nagios is configured. It checks and records the packet loss as a percentage. This improved the availability of the network since connectivity was checked at constant intervals, as soon as there are no packets received the teacher in charge at the either of the schools can call the other school to check if everything is switched on. Results obtained from these pings were recorded and are outlined in the next chapter. To make sure connectivity is available at all times a php script “*net-monitor*” shown in *Appendix 5* was added as a plug-in to Nagios. This net-monitor works under the assumption that all the equipment is plugged in and there is power available. The *net-monitor* sends out a ping request to the server at Ngwane. If the packet loss is less than 50% then the network is working fine. If the packet loss is greater than 50% then the ping request is sent 3 more times and if the same result is obtained then a Wake on LAN signal is sent and the host is rebooted.

```

define timeperiod{
    timeperiod_      name 24x7-
    alias            24 Hths A Day, 7 Days A Week
    sunday           00:00-24:00
    monday           00:00-24:00
    tuesday          00:00-24:00
    wednesday        00:00-24:00
    thursday         00:00-24:00
    friday           00:00-24:00
    saturday         00:00-24:00
}

```

#### *Configuration segment 4.5: Monitoring periods*

Configuration segment 4.5 specifies the time periods when the network can be monitored and notifications can be sent. This gives the administrators a clear view of the activities and performance of the network.

The Nagios interface can be accessed at the site by typing `http://mpume-server/nagios` on the web browser at the school where it has been deployed. For security reasons, the administrator

is supposed to logon by inputting a username and password. The services that are monitored using Nagios are the number of current users, protocols used at Mpume, connectivity, partitions and disk usage. A detailed description of these services and some of the results obtained are discussed in Chapter 5.

### ***Problem***

*Internet not available-* The availability of the network is affected by broken equipment that has to be taken back to the universities (Fort Hare and Rhodes). This increases the network's downtime since at least a period of a week passes before the equipment is returned to the site.

### ***Solution***

At each of the schools we have extra equipment such as network cards, cables, RAM, a couple of monitors and systems units. This improved the uptime of the network because no time was wasted in waiting for equipment coming from the universities, as some of the broken computer equipment can be replaced on site, since the teachers in charge at the sites were taught how to replace network cables and RAM. Only seriously damaged equipment that needed greater attention was taken to the universities for fixing.

### ***Problem***

*Improper network configurations-* Configurations on the server and the router were corrupted at times and, as a result, the servers and routers failed to boot properly. Unfortunately, the servers and routers had to be taken to the universities for reconfiguration.

### ***Solution***

To solve the problem of configurations being corrupted and users having to wait for the next visit by the administrators to take the servers and routers then bring them back after reconfiguration, we deployed a backup system called Simple Backup which can be used by trained administrators at different schools to get the correct backup configurations. This backup system keeps all the files in */var, /home, /usr, /local, /etc, /root*. The backup files are sent to the local and remote administrator's email and the same copy of the backup files is stored in */var/backup* on the machine. The correctness of the backed up configurations is checked by the administrator; if a problem occurs, the teachers at the site communicate with

the administrator before they conclude that the problem was caused by corrupt configurations and making changes. We configured the backup system in such a way that it does a backup once every week. The backup is done once a week because the network is small and configurations are not changed at regular intervals. A full backup of the whole system is done after every 14 days but backups older than 60 days are deleted from the /var/backup although they remain in the administrator's inbox. The old configurations are recovered by accessing /var/backup when you are logged on as the root user.

### ***Problem***

*No internet connection for some days-* The users at Mpume did not have internet for days on several occasions because the equipment was not properly plugged in.

### ***Solution***

To solve this problem we put an individual in charge of the lab at each of the four schools. This person checks the connections frequently and a poster was designed for them, as shown in *Appendix 3*, to illustrate how the hardware devices should be connected. In order to minimise the unnecessary moving of equipment, the equipment was put in a lockable computer rack as shown in Figure 4.3. Also, a poster illustrating how the equipment is connected inside the server racks at each of the schools is shown in *Appendix 6*.



*Figure 4.4: Equipment put in a lockable rack*

### ***Problem***

*Shortage of electricity-* The users at Mtokwane, Ngwane and Nondobo lost their internet connection because the users at Mpume had switched off their equipment trying to save electricity.

### ***Solution***

The people within the community can start fund raising projects to raise money to buy electricity. In addition, the teachers in charge of the network at the schools should agree on the time at which they have to switch their servers and the routers on and off. Figure 4.4 shows some of the community members at one of the community meetings.



*Figure 4.5: Picture of some of the Community members*

## ***Problem***

*Environmental factors-* From the previous chapter we have seen that the WiMAX micro-base-station was significantly affected by lightning.

## ***Solution***

To protect the base station we deployed lightning arrestors at Ngwane. At all the schools, the equipment in the lockable racks is connected to the Uninterruptible Power Supply (UPS) units so as to protect them from unexpected power failures. Figure 4.6 shows the deployed lightning arrestors at Ngwane.



*Figure 4.6: Lightning arrestors at Ngwane*

Table 5.1 shows solutions that we have implemented and other feasible solutions that can be implemented to solve the problems experienced on the network. This table has three main categories which are the problem, solutions and who can solve the problems when they occur. This last category is subdivided into three sections, which are:

*Users*                      These are the people that use the equipment on a day-to-day basis such as the teachers, community members and the learners.

*Administrators* These are people who are in charge of the deployment, maintenance and upgrades done on the network site.

*Service providers* These are the people from the companies that provide the service, such as Telkom.

*Variable X* Indicates who can solve the problems when they occur.

In addition to the problems and solutions discussed above, below is a table that summarises other network solutions that have not been implemented on the SLL.



Table 4.5: Summarised list of possible solutions that were not implemented

Problem	Solution	Solver	
		Administrator	Users
The peripheral devices of thin clients, servers or the Mpume access concentrator are sometimes intentionally disconnected.	Attach hardware components to the systems unit using either glue or any other adhesive. A keyboard, video or visual display unit, mouse, Kernel-based Virtual Machine (KVM) switch can be introduced where multiple computers can be controlled from a single keyboard, video monitor and mouse. So, in the SLL the servers and the routers can be connected to a single set of keyboard, mouse and monitor.	X	
Equipment such as keyboards and mice are broken and the users have to wait for the next trip to have them replaced.	Create an equipment storeroom where extra pieces of equipment such as RAM and keyboards are kept for quick replacement when the ones in use are broken.	X	
The electricity in Dwesa is not always available.	Introduce other forms of energy such as a solar panel or biogas.	X	X
Teachers switching off equipment trying to save electricity.	Do monthly fundraising for electricity money.		X

#### 4.6 Conclusion

Having identified several network solutions, we tried to select those which were applicable to the SLL network. The introduction of the backup GPRS redundant link has improved the connectivity on the deployed network. In addition, the various monitoring systems have enabled the administrators to keep an eye on the network and, as a result, solve problems before they even occur. This has improved the robustness of the deployed SLL

telecommunication network. The next chapter discusses some of the results that were obtained from various experiments conducted on the SLL network.

## **Chapter Five: Experimental tests and results**

### **5.1 Introduction**

We performed several tests on the redundant link and on the network monitoring systems. The initial tests were done in a smaller lab environment at the University Of Fort Hare (UFH) where a network similar to the SLL was created before the actual deployment on the SLL network. We did not include the results that we obtained at Fort Hare because the primary focus of our research was the network in Dwesa. This chapter discusses the various tests that were conducted and the results that were obtained.

### **5.2 GPRS Ping tests and results**

The following actions were done to simulate the switching between Local Area Network (LAN) and the Wide Area Network (WAN) links.

- Unplugged the cable that connects the VSAT unit and the server, so as to imitate what happens when the VSAT link goes down;
- Plugged the cable that connects VSAT unit and the server back in and observed what happens to the GPRS link when the VSAT link was up again.

Ping tests were the key tests in the experiments; we sent a ping request to the computers on the networks and the replies were used to measure the round trip time (RTT) of the network. Ping requests were sent, at 30 minutes intervals, to the access concentrator so as to monitor the LAN. To communicate with the WAN, ping requests were sent to the [www.ru.ac.za](http://www.ru.ac.za) site to monitor GPRS connectivity. The ping results enabled us to determine the minimum, maximum and average round-trip time to a remote computer. The number of packets that were returned indicated the reliability of the networks. The network failure, in this case, is detected when no packets are received when the ping command is issued or by the message “Host is down” on the command line interface.

Tests were done on the router to check the connectivity pattern of the router when:

- Both the GPRS and the WAN were up
- Only the GPRS was up
- Only the WAN link was up

- When switching was taking place

### 5.2.2 Test done on the SLL network

Figure 5.1 shows the results obtained from the ping tests done on the VSAT network at a given moment in time. From the results, we notice that the Round Trip Time (RTT) of the network was not constant as evident in the great fluctuations on average RTT results. The average RTT of this network was about 27ms which showed that the VSAT connection speed was good and there was minimal packet loss. From these results, we see that the instantaneous minimum RTT for the network is 8ms. The RTT instantaneous average value increases from 12:30 to 13:00 because, during this time, there many people were accessing the network.

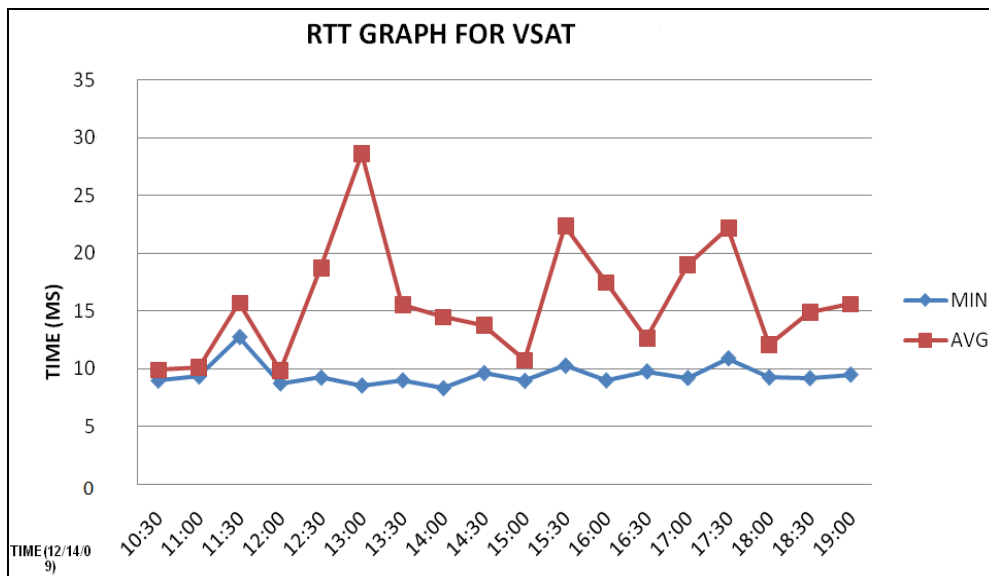


Figure 5.1: RTT for VSAT

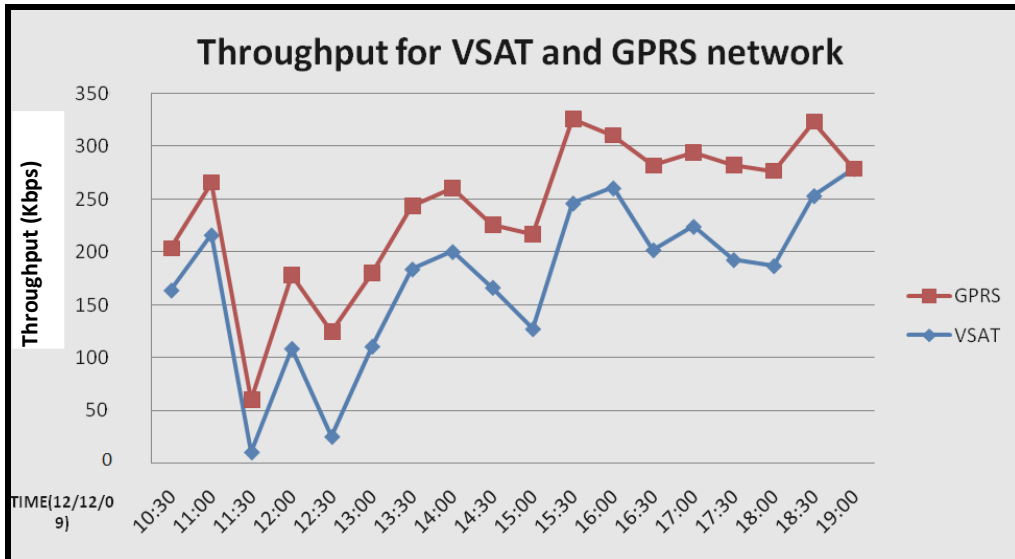


Figure 5.2: VSAT and GPRS throughput

The throughput shown in Figure 5.2 was obtained when the networks were operating at the same time. We noticed that there was a drop on both networks at 11:30 because users were accessing both networks at this time. The throughput for the networks increased gradually from 13:00 to 14:30 because there were few users accessing the network and the VSAT had its maximum throughput of 260Kbps at 16:30 when a 1000KB file was downloaded and the GPRS had its maximum throughput of 330Kbps at 15:30 when a file of size 700KB was downloaded.

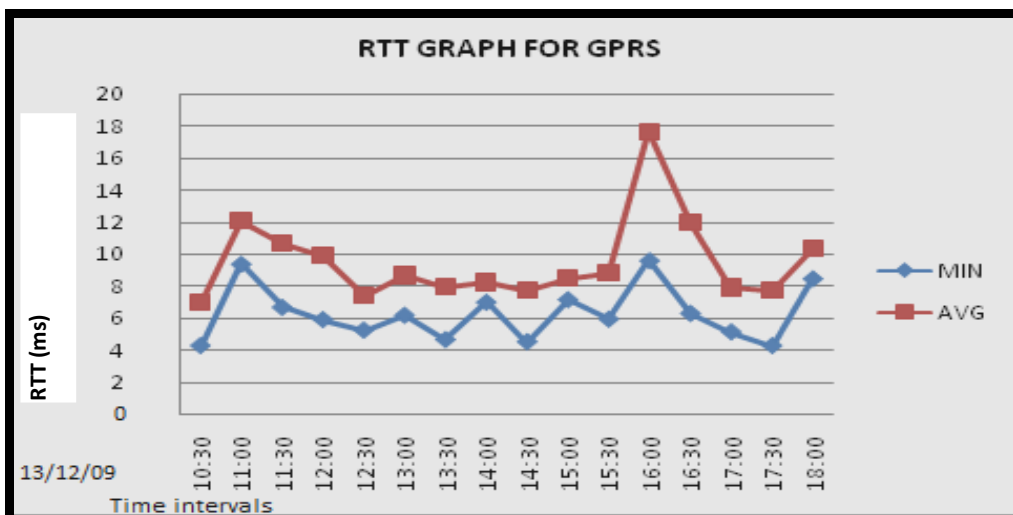














Figure 5.3: Ping test over the GPRS network

Figure 5.3 shows the results obtained from the ping tests conducted on the GPRS network. From the results, we noticed that the instantaneous Round Trip Time (RTT) of the network was not constant as shown from the great fluctuations on average RTT results. The average RTT of this network was about 18ms which showed that GPRS connecting speed was fast. From these results, we see that the minimum RTT for the network is 4ms. The RTT instantaneous average value increases from 15:30 to 16:00 because the network was congested since many people were accessing the network during this period.

### **5.3 Nagios test and results**

As stated before, besides the GPRS redundant link, Nagios was also used as a monitoring tool and below are some of the results obtained from the test done at Mpume. The monitoring system was deployed at Mpume because this is where the VSAT network is deployed and this school acts as a primary link to the other schools. Two major scenarios were tested on Nagios, these are:

- Running Nagios when everything on the network is working fine,
- Running Nagios when the server and the router at Ngwane are not switched on.

	Service  	Status  	Last Check  	Duration  	Attempt  	Status Information
<a href="#">localhost</a>	<a href="#">Current Load</a>	OK	12-12-2009 10:15:54	0d 0h 6m 33s	¼	OK - load average: 0.06, 0.18, 0.17
	<a href="#">Current Users</a>	OK	12-12-2009 10:16:32	0d 0h 5m 55s	¼	USERS OK - 3 users currently logged in
	<a href="#">HTTP</a> 	OK	12-12-2009 10:17:09	0d 0h 5m 18s	¼	HTTP OK: HTTP/1.1 200 OK - 337 bytes in 0.001 second response time
	<a href="#">PING</a>	OK	12-12-2009 10:12:47	0d 0h 4m 40s	¼	PING OK - Packet loss = 0%, RTA = 0.08 ms
	<a href="#">Root Partition</a>	OK	12-12-2009 10:13:24	0d 0h 4m 3s	¼	DISK OK - free space: / 106539 MB (75% inode=97%):
	<a href="#">SSH</a> 	OK	12-12-2009 10:14:02	0d 0h 3m 25s	¼	SSH OK - OpenSSH_4.7p1 Debian-8ubuntu1.2 (protocol 2.0)
	<a href="#">Swap Usage</a>	OK	12-12-2009 10:14:39	0d 0h 2m 48s	¼	SWAP OK - 95% free (1837 MB out of 1945 MB)
	<a href="#">Total Processes</a>	OK	12-12-2009 10:15:17	0d 0h 2m 10s	¼	PROCS OK: 83 processes with STATE = RSZDT

*Figure 5.4: Screenshot showing the summary of the status of the services at Ngwane*

Figure 5.4 shows the results obtained when the network was operating normally. The services that are monitored by Nagios are shown in the service column below. These results indicate that the status of the services was OK. On the status information, the status of each service is described; for example, on the current users at the time of the test there were 3 users who were logged on at 10:16:32. The packet loss was 0% and the RTA was 0.08ms.

State	Type / Reason	Time	% Total Time	% Known Time
UP	Total	0d 0h 27m 6s	100.000%	100.000%
DOWN	Total	0d 10h 0m 0s	0.000%	0.000%
UNREACHABLE				
	Total	0d 10h 0m 0s	0.000%	0.000%

*Figure 5.5: Summarised performance of the network from the*

The monitoring system was scheduled to monitor the uptime and downtime percentages of the services and the host in a period of 10hrs; the results were tabulated as shown in Figure 5.5. The uptime refers to the time when the servers and router were running properly on the network; we could ping the server and the router at Mpume. After getting positive results, a phone call was made to the users at Mpume to switch off their router servers as represented by the term. The period when the server was off is shown by the term “DOWN” was obtained. From these results, we notice that nothing was recorded and the total network uptime was 0%. At the same time, since the network was down all the hosts on the network were “UNREACHABLE”.

Figure 5.6 shows a percentage breakdown of the host services at Ngwane when the network was running well. From this table we see that all the monitored services on the host had 100% uptime.



Service	% Time OK	% Time Warning	% Time Unknown	% Time Critical	% Time Undetermined
<a href="#">Current Load</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
<a href="#">Current Users</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
<a href="#">HTTP</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
<a href="#">PING</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
<a href="#">Root Partition</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
<a href="#">SSH</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
<a href="#">Swap Usage</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
<a href="#">Total Processes</a>	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%
Average	100.000% (100.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000% (0.000%)	0.000%

*Figure 5.6: Up- and downtime for each service*

The results shown in Figure 5.7, below, were obtained when the network at Mpume was down. As part of the test we switched off the server at one of the schools (Ngwane) and viewed the status of the services at Mpume. These results indicated that all the services on the network were unavailable for a period of approximately 30minutes.



Host ↕	Service ↕	Status ↕	Last Check ↕	Duration ↕	Attempt ↕	Status Information
Mpume-server	<a href="#">Current Load</a>	CRITICAL	12-12-2009 16:23:36	0d 1h 8m 43s	¼	service not available
	<a href="#">Current Users</a>	CRITICAL	12-12-2009 16:19:14	0d 1h 8m 5s	¼	service not available
	<a href="#">HTTP</a> 	CRITICAL	12-12-2009 16:19:51	0d 1h 7m 28s	¼	service not available
	<a href="#">PING</a>	CRITICAL	12-12-2009 16:20:29	0d 1h 6m 50s	¼	service not available
	<a href="#">Root Partition</a>	CRITICAL	12-12-2009 16:21:06	0d 1h 6m 13s	¼	service not available
	<a href="#">SSH</a> 	CRITICAL	12-12-2009 16:21:44	0d 1h 5m 35s	¼	service not available
	<a href="#">Swap Usage</a>	CRITICAL	12-12-2009 16:22:21	0d 1h 4m 58s	¼	service not available
	<a href="#">Total Processes</a>	CRITICAL	12-12-2009 16:22:59	0d 1h 4m 20s	¼	service not available

Figure 5.7: Nagios negative results

## 5.4 Cacti results

As discussed in the previous chapters, Cacti was used as our local monitoring system and we used it to obtain the graphical representation of the performance of the network as well as different services running on the network. Below are graphs representing the various parameters that we measured on the network and Ngwane. We used the results for Ngwane because this is the school with the highest number of users and the WiMAX base-station is deployed at this school.

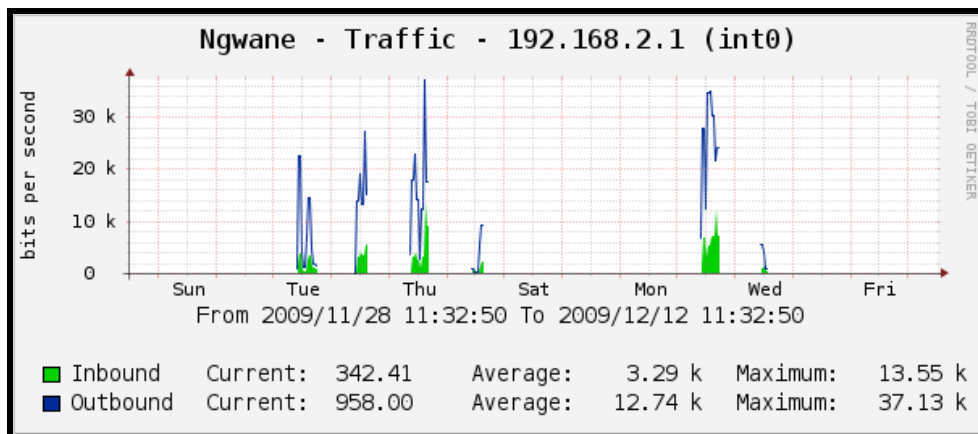


Figure 5.8 Traffic on the internal interface (int0)

Figure 5.8, above, shows the traffic on the local area Ethernet interface (int0) at Ngwane. The Inbound LAN traffic at Ngwane is slightly high on the days in which the data was collected, as shown in the graph. From the results, we see that the inbound average is 3.39kbps and the expected maximum is 13.55kbps which means that 13.55kbps were transferred into the network on the Tuesday when the test was done. On the same interface, the average outbound traffic is 12.74kbps and the maximum outbound traffic was 37.55kbps for the day when the test was done. The blank days (Monday, Friday, Saturday and Sunday) are the days when the computer lab was not in use and there was no traffic on the network.

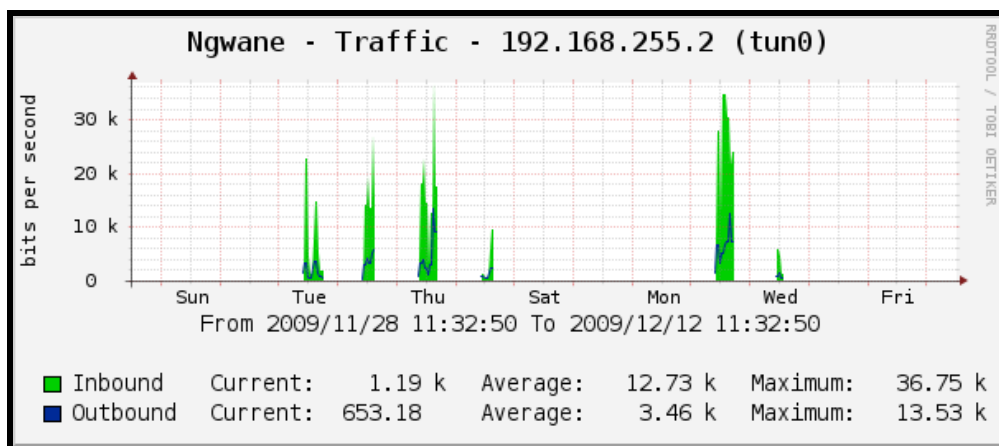


Figure 5.9: Traffic on the WAN interface (tun0)

Figure 5.9 shows the traffic on the Wide Area Network (WAN) Ethernet interface (tun0). This is the interface that connects Ngwane to the VSAT network at Mpume. From the Inbound WAN traffic at Ngwane, we see that the inbound average is 12.73kbps and the expected maximum is 36.75kbps; this means that the 36.75kbps can be transferred into the WAN at a given period. On the same interface the average outbound traffic is 3.46kbps and the maximum outbound traffic is 13.53kbps. As shown in the graph, there was no traffic on Friday, Saturday, Sunday and Monday; this is because the school is closed over the weekend and the computer lab is not used on Mondays and Fridays.

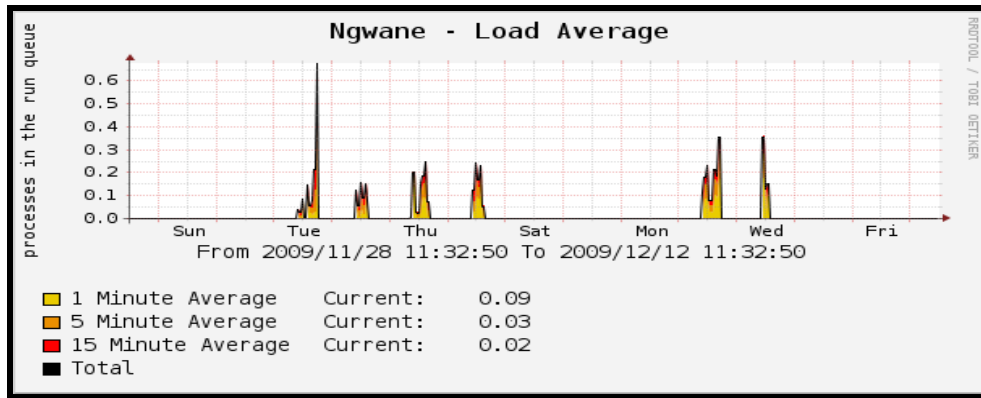


Figure 5.10: Load average

The Load average on the server at Ngwane is shown in Figure 5.10. We defined the load average as the number of processes waiting in the queue per given interval. The load average was measured in the 1minute, 5minute and 15minute intervals. The load average differed for each interval and the shorter the interval the more the number of processes in a queue. From the graph, we see that at the 1 minute interval the load balance was 0.09 processes and at 5 minute intervals the load average was 0.03 processes while at 15 minute intervals the load average was 0.02 processes. This indicates that the load balance varies gradually over time. As shown in the graph, there was no traffic on Friday, Saturday, Sunday and Monday; this is because the school is closed over the weekend and the computer lab is not used on Mondays and Fridays.

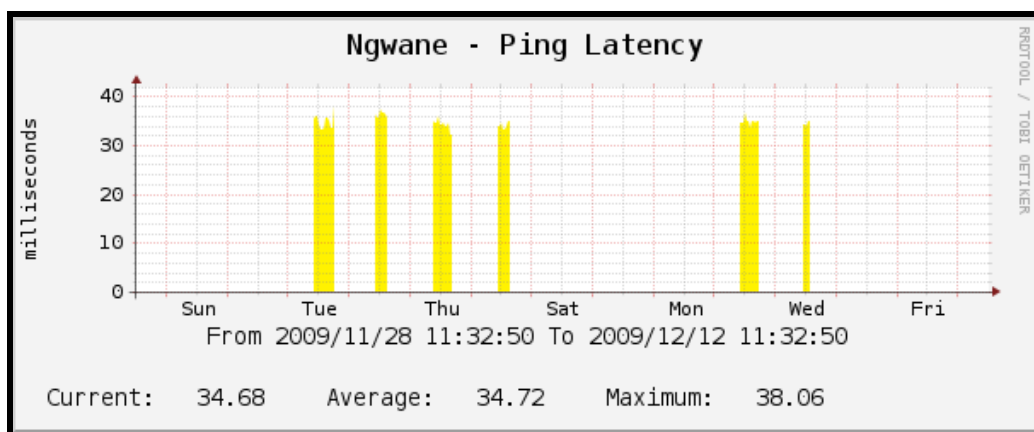


Figure 5.11: Ping latency

Ping was the main tool that we used to check connectivity. As a result we decided to have the ping latency measured and represented graphically by Cacti. Figure 5.11 shows the graphical

representation of the ping latency results that were obtained after sending a ping request to the Mpume server. At the time at which the results were captured the ping latency was 34.68ms and the average ping latency was 34.72ms; this means that the ping latency at this particular time was lower than the average and the maximum ping latency which is 38.06ms.

### **5.5 Summary of results**

Network performance parameters such as throughput, reliability and latency for the deployed access technologies were measured. These results showed how the throughput and latency of VSAT and GPRS behave when they are both plugged in and working at the same time, and when one of them is in operation separately. In addition, a constant automatic and reliable switch over to GPRS was achieved when the VSAT network went down. For the GPRS network we noted that its download speed was 312Kbps and upload speed was 128kbps. For the VSAT, network its upload speed was 232Kbps and its download speed was 96Kbps. This implies that the speed on the network was increased when the network accessed the internet using the GPRS network. We made sure that the GPRS network is only accessed when the VSAT network is down, so as to cut the cost of running the whole network on GPRS all the time.

### **5.6 Conclusion**

The results outlined above have provided an overview of the experiments we carried out. From these results we see that the availability and monitoring of the SLL network were improved. The next chapter concludes the thesis.

## **Chapter Six: Summary, Discussion and Conclusion**

### **6.1 Introduction**

The chapter presents the summary of the research. It explains the achievements of the system and other solutions which were suggested to solve the SLL network problems. The chapter also suggests some ideas that can be considered for future deployments on the SLL network.

### **6.2 Summary**

A number of access technologies, network monitoring and backup tools were evaluated for their applicability in improving the running of a rural network. Under access technologies: Wi-Fi, GPRS, HSDPA and 3G were evaluated to see if they were compatible with the already deployed technologies since they were supposed to act as backup systems for the VSAT and the WiMAX.

In terms of monitoring systems: Zenoss, Nagios, Cacti and Zabbix were evaluated and they were deployed on the SLL network. A variety of results were noted. Going through the results culminated in the decision to deploy Nagios and Cacti as our monitoring systems on the SLL network. For the backup systems, several systems were evaluated but we ended up deploying sbackup and Webmin backup tools.

The goal of this research was to implement solutions for the deployed SLL telecommunication network. The solutions that we implemented were supposed to be cost effective, through the use of open source software. The solutions we implemented were to be of benefit to those living in rural areas. We taught the people in the community how to make use of the deployed infrastructure in order to promote their own businesses. This was achieved by a study of the various solutions that have been implemented by other rural telecommunication networks in South Africa.

### **6.3 Achievements**

The constant availability of Internet connectivity on the SLL network services have improved the quality of education in the schools under the SLL project, since teachers and students are

now making use of different E-learning curriculums. For the community at large, the reliable availability of the Internet has improved their way of life since they can now communicate with their relatives through emails and online sms's. The different e-service projects which form part of the SLL are now easy to setup as the network is now more reliable.

The study has provided insight into practical and cost effective solutions that can be used to improve the availability of rural telecommunication networks. In this case, GPRS technology has proved to be a reliable redundant link for the VSAT network on the SLL network. Constant monitoring of the network was achieved through updates from Nagios and a clear graphical representation of the different parameters that were measured on the network was shown through the use of Cacti.

Backups of critical configurations were also obtained and stored through the use of Sbackup and Webmin. The utilization of Free and Open Source Software (FOSS) for monitoring and creating backups on the network have proved to be cost effective solutions on our network since no cost were incurred during the deployment of these systems.

### **Summary of the achievements**

- Ability to monitor the network;
- Reliable network with a backup plan;
- A comparison of different network technologies and backup strategies, and being able to choose and implement the best;
- Improved availability of network services.

### **6.4 Status of the deployed solutions**

The local monitoring and backup systems were deployed at the schools (Ngwane and Mpume). The remote monitoring system was deployed at the two schools. No email has been sent to the administrators since their deployment; this indicates that the network has not experienced any major failures. General feedback on the server status, i.e. whether it is up or down, is constantly being sent to the server at Fort Hare from the monitoring script deployed at Mpume.

## **6.5 Limitations**

Despite the reliable switchover between the VSAT and the GPRS the performance of the GPRS network depends on the availability of the Vodacom network, which is our Internet Service Provider (ISP).

The cost of running the GPRS on the network can be viewed as expensive. However, to cater for this cost we blocked access to the File Transfer Protocol (FTP) as well as sites such as Youtube, facebook and skype chat rooms when the network is running on GPRS. This restricted the users to only doing academic work when the GPRS is in use. We did not do this for the VSAT network because there was a fixed charge for VSAT usage and the bandwidth seems to be enough for the SLL network. This means that users will still be able to access the entire site when using the VSAT network.

## **6.6 Future Work**

Putting the above mentioned limitations into consideration the following improvements can be made on the SLL network:

- Have someone on the network site who is trained on how to use WiMAX equipment who can solve the problems instantly
- Training of users on the advanced network trouble shooting techniques by offering courses such as Linux+ and Network+;
- Deploy Wi-Fi access points that do not depend on the WiMAX network. The access points can be used to access the Internet at the schools.
- To date there has been tremendous changes on the SLL network, which means there is need to adjust the monitoring systems to cater for the changes and cover the new schools that have been introduced onto the network
- There is already a new network diagram and more ways to improve the monitoring should be in place.

## **6.7 Overall Conclusion**

Provision of reliable network services is one of the objectives in this research. Therefore, in this research we have taken into consideration different factors, systems and strategies which could enable this. We can conclude that after the deployment of the monitoring system and



network backup solutions the SLL network has been efficient. This has enabled the deployment of different projects. Since the applications we used are freely available (Open Source Software) e.g. Nagios and Cacti, this gives room for any future changes on the network. Additional features and applications to improve the network services are possible. We expect the Dwesa community to have better services available in making use of the reliable network services provided in this research.

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## Appendix 1

### Dwesa network diary starting from February 2008

Date	Problem	Solution
24 February 2008	The computers and the micro base station at Ngwane were not working. It was suspected that these pieces of equipment had been struck by lightning.	Ingrid and I organised a trip to the site and deployed lightning arrestors and replaced the WiMAX micro base station. The deployment of the arrestors was meant to prevent equipment from being struck by lightning.
17 March 2008	Mrs Gxarisa reported that there was no internet at Mpume.	A trip was organized and an access concentrator cable was not properly plugged in, so we plugged in the access concentrator to the power supply and the network started up.
15 April 2008	Dr. Mamello reported that the access concentrator at Mpume was not working. From his analysis he concluded the fan needed replacing. Also on the same network, the switch was frequently losing its power.	The switch's power supply was replaced and the fan for the access concentrator was replaced.
22 May 2008	Pinky reported that the users at Mpume were failing to open the web browsers and, on other computers, these were freezing.	When Ingrid and I went to the site we realised that there was a problem of people signing in as one user on different computers and, as a result, the computers with the same users signed in froze when the users tried to access the web browser. We urged the users to always use different user accounts and this solved the problem of the computers freezing when accessing the browser.

15 June 2008	Theresa at Ngwane reported that there was no internet and when Ingrid went to the site she realized that the router had crashed.	Ingrid took the router to Graham's town and fixed it from there; it was returned to Dwesa 3 weeks later when the next trip was organized.
20 June 2008	Some of the problems faced on the site were a result of some of the equipment being switched off as a way of trying to save electricity.	Dr. Mamello organized a local committee that was responsible for making decisions such as when the network goes on or off and making sure that everything is turned on. Unfortunately, there were problems in sustaining the committee hence it did not last for a long time.
1 August 2008	Ronald reported that the router at Ngwane was not booting properly.	The router was taken to Rhodes and Ingrid replaced the power supply of the router and the problem was solved. The router was taken to the site on the next trip.
20 August 2008	Mitchell reported that a computer monitor was not displaying anything on the screen.	New graphics cards were installed on the computers and the problem was solved.



26 September 2008	Theresa reported that there was no internet at Ngwane.	Theresa was advised to check whether the server and the router were switched on and when she realised that only the server was switched on, and after switching on both sets of equipment, the network was up again.
13 October 2008	Ingrid reported that the network at Mpume was down.	Using the backdoor channel, Ingrid realised that there was nothing broken on the site. The loss of connection was due to the server that was not switched on at Mpume. A phone call was made to Mrs. Gxarisa who switched on the server and the access concentrator and network were active again.
11 November 2008	Pinky reported that there was no internet at Mpume.	Various tests were done to try to identify the problem on the network because all the schools on the network were affected by this problem. Memory notified Telkom technicians of the problem and they went to the site. At the site they realised that the problem was the satellite's Low Noise Block (LNB). It took about two weeks before they replaced the LNB and after replacing the network was active again.
23 March 2009	Mitchell reported that the internet was down at Ngwane.	The router was reconfigured and replaced.

## **Appendix 2**

### **Dwesa Networking Document**

Ingrid Siebörger, Barry Irwin

October 22, 2007

Document Version 1.0

#### **1 Introduction**

This document serves to describe and explain the network, servers and services at the Dwesa Siyakhula project, jointly run by the University of Fort Hare and Rhodes University. It is hoped that this document will assist any new administrators or service providers within the project to understand the current configuration within the network.

#### **2 Dwesa Routers**

At each of the schools, currently Ngwane, Mtokwane and Nondobo (with Nqabara to come on board in the next phase) there is a FreeBSD 6.1 computer acting as a router. They are all low end Intel Pentium III systems

- The current router at Ngwane has an asset number of 18182
- The router at Mtokwane has an asset number of 13485
- The Nondobo router has no asset number, but again the machine is of a similar kind.

#### **3 Dwesa Access Concentrator**

The Dwesa access concentrator establishes communication tunnels on the WiMAX network with the other routers at each of the schools. This system is a Pentium III 500MHz processor, whose asset number is 15739. This server is the router for the WiMAX test bed network in Dwesa. It runs a pppoe service for the clients on the network. This allows for authentication and encryption preventing non-authorized access and securing traffic. The router runs FreeBSD 6.2.

#### **4 The network**

At each of the schools there is a local area network (LAN) allowing the local lab and school computers to communicate with the school's server and the school's router which will route them to the Internet. The schools and their subnets are as follows:

- Ngwane 192.168.2.0/24 (i.e. the subnet mask is 255.255.255.0)
- Mtokwane 192.168.3.0/24
- Nondobo 192.168.4.0/24
- Nqabara 192.168.5.0/24

Each school router has two network cards: an internal network interface and an external network interface. The internal interface, called `int0`, has an IP address within the range of the LAN. Physically `int0` is connected to the switch at the school. The external interface, called `dcw0`, binds an IP address on the “raw” WiMAX IP network. This “raw” network operates in 169.254.0.0/16 (i.e. the subnet mask is 255.255.0.0). Physically `dcw0` is connected to the WiMAX network. This means at Mpume, Mtokwane, Nondobo and eventually Nqabara their network is connected to the WiMAX CPE, while at Ngwane it is connected to the base station. Each of the routers binds an IP on this network as follows:

- Ngwane 169.254.0.2
- Mtokwane 169.254.0.3
- Nondobo 169.254.0.4
- Nqabara 169.254.0.5

This “raw” network allows these machines to communicate with the Access concentrator, located at Mpume, which binds the IP of 169.254.0.1 on the network interface (network card) that is connected to the WiMAX network. The other network interface is connected to a backbone network with the Mpume server. This network block is 192.168.0.0/24 and the network interface on the Access concentrator binds the IP address 192.168.0.2. Currently, this network interface is plugged into a network interface on the Mpume server directly, instead of going through another switch, using a cross-over network cable.

Each of the routers at the schools are configured so that when they receive packets from within their LAN that are meant for computers on another networks, including the Internet, they will forward them on to the next known network/router that they are connected to. In FreeBSD this is easy to configure, during installation you set the machine up to be a gateway, otherwise if you wish to configure it post installation then it will be a matter of setting the variable of “gateway enable” to true in `/etc/rc.conf` then reboot.

Since the WiMAX network is not encrypted, virtual network links are created from each of the routers to the access concentrator across the “raw” network. The PPPoE protocol (with MPPE encryption) is used to establish these virtual links. The reason behind doing this is that the traffic will be encapsulated within an authenticated, encrypted pipe protecting the content of the traffic from man in the middle attacks or traffic sniffing (which is easier to perform on wireless network than a wired network). In addition, it increases the security in terms of only allowing authenticated users to join the network and it reflects real world network service providers.

The access concentrator runs a PPPoE service. Each of the routers will then use the “raw” network to establish a PPPoE session, authenticating itself with a username and password to the access concentrator, which then checks the credentials (against a plain-text password list) and establishes the PPPoE session. All traffic from the school’s LAN to the rest of the



network or the Internet is then routed via that tunnel. The access concentrator provides each of the school routers with a PPPoE IP address in the range of 192.168.255.0/24, as follows:

- Ngwane 192.168.255.2
- Mtokwane 192.168.255.3
- Nondobo 192.168.255.4
- Nqabara 192.168.255.5

The far end of the PPP session is the access concentrator's IP address on the backbone network, 192.168.0.2. This means that each of the routers is able to forward traffic from the local network intended for the rest of the network or the Internet securely to the access concentrator which will then route it onto the correct network, either to another school in Dwesa or to the Mpume router to be sent on to the Internet. The access concentrator will pass on all Internet traffic and traffic for the Mpume local network to the Mpume server.

The Mpume server contains three network cards. One of which connects to the backbone network with the access concentrator and binds the IP address 192.168.0.1. Another network interface binds an IP address on the 2 local networks at Mpume, allowing the school's local computers (thin clients) to communicate with the server. This IP address is 192.168.1.1. The local IP block for the LAN at Mpume is 192.168.1.0/24. The third and final network interface connects to the VSAT. This network interface binds an IP within the 10.0.0.0/8 range (configured via DHCP) and will change constantly as part of how Telkom seems to run their network.

Incoming network traffic will either be intended for other computers on the LAN, or the Internet, or needs to be sent to one of the other school networks. If traffic is for the LAN, then the server will route it locally; if it is intended for the Internet, then it will route the traffic out over the VSAT connection and if it is intended for one of the other school networks, then it will forward it on to the access concentrator. Thus, the Mpume server is configured such that its default gateway is the VSAT connection (10.x.y.z) with static routes so that it can reach the LANs of the other schools via the access concentrator:

- 192.168.2.0/24 via 192.168.0.2
- 192.168.3.0/24 via 192.168.0.2
- 192.168.4.0/24 via 192.168.0.2
- 192.168.5.0/24 via 192.168.0.2

Similarly, the access concentrator will have static routes configured for the school LANs via the PPPoE sessions that have been created between it and each school router.

- 192.168.2.0/24 via 192.168.255.2
- 192.168.3.0/24 via 192.168.255.3

- 192.168.4.0/24 via 192.168.255.4
- 192.168.5.0/24 via 192.168.255.5

While the default gateway for the access concentrator is the IP address of the Mpume server on the backbone network, 192.168.0.1.

## **5 Adding new subscribers**

To add new subscribers to the system is very easy. All you need to do is edit the subscribers file in /root/admin. You will see from the headings in the file that you need to provide the following details for the new subscriber:

- username
- password
- router ip address
- point to point protocol ip address
- subnet
- network address

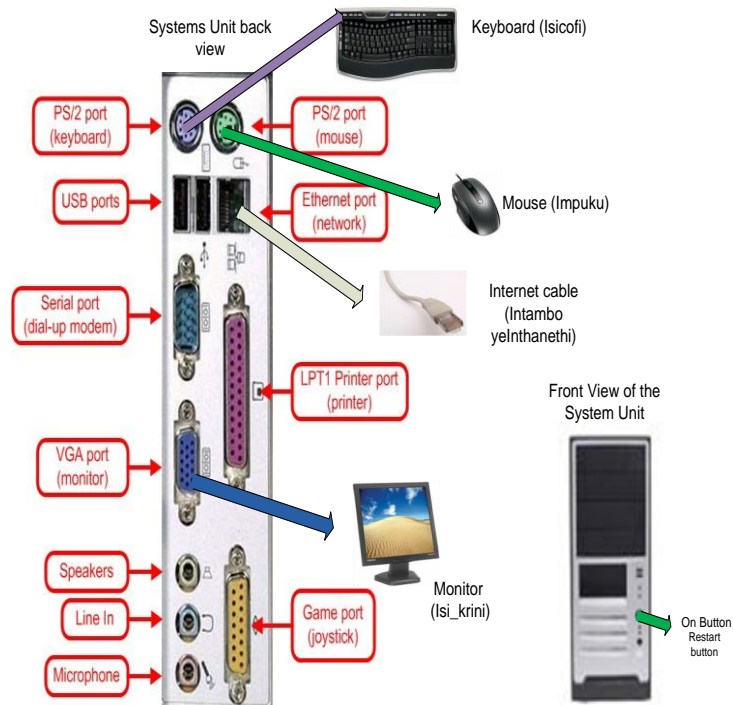
Once those have been added to the file, save it and run make from within the /root/admin directory. This will create the PPP account for you and put in place the necessary variables for creating routing tables when the subscribers log onto the system. In addition, it also puts into place the ability to graph the traffic generated by each of the subscribers.

## **6 Traffic graphing and statistics**

Traffic graphing and statistics is handled by firewall rules and a statistics gathering system, which stores the statistics using RRDTools. The firewall rules count the traffic generated for each PPP connection to the local network within Dwesa and then also the traffic that they generate for the Internet. These values are then passed onto RRDTools which stores the values over time. More precise data is kept for the most recent traffic and as we go back in time the data are less accurate as they are averaged over the time passed. The Dwesa Access concentrator runs an Apache web server which serves CGI scripts which use RRDTools to draw graphs based on the data in the RRD databases. The graphs can be accessed at:

<http://dwesaac.dwesa.org.za/~stats> from within the Dwesa network.

### Appendix 3: Poster showing how to connect peripheral devices



BEFORE PRESSING THE "ON" BUTTON MAKE SURE  
EVERYTHING IS PROPERLY CONNECTED TO THE CPU  
CASE

(QINISEKESA UKUBA ZONKE IZINTO ZIDIBENE  
(Intambo, impuku, isicofi) KWI CPU PHAMBI KOKUBA  
UCOFE ICOFE IQHOSHA LEKHOMPUTHA )

## Appendix 4

This report aims to clearly state the steps required to get the system working. This might help everyone better troubleshoot network related problems on the SLL network.

At each school the following steps need to be taken:

### Ngwane:

1. Is the WiMAX base station on? The power light should be green and the ODU 1 alarm light should be off.
2. Is the router on? Plug in a monitor, see that it has booted. Log in, run `ifconfig` and check that that `dcw0` and `int0` have active status.
3. Can you see a `tun0` interface on the router? Does it have an IP? associated with it, 192.168.255.2? If not can you ping 169.254.0.1 from the router?
4. Is the server on? Check that the server can ping the router, 192.168.2.1?
5. Run Firefox, is the proxy manually set to use the proxy server at Mpume, 192.168.0.1 Port 3128?
6. Ngwane is reliant on Mpume for connection to the Internet, thus ALL the Mpume steps below must be done for Ngwane in order to help diagnose errors.

### Mpume:

1. Is the WiMAX CPE on? Can you see that there is signal strength on the bottom of the CPE?
2. Is the VSAT on? Are the power, TX, RX, etc lights on the receiver on?
3. Is the router on? If it's OFF switch it ON and when it's ON:  
Log into it, run `ifconfig`, can you see a bunch of `tun` (`tun0`, `tun1`, `tun2`, etc) connections listed and are the network interfaces active?
4. Is the server on? If it's ON
5. Run `ifconfig`. Has the `eth0` interface been assigned an IP in the range of? 10.0.0.0/8 from the VSAT? If YES
6. Can you ping the router, 192.168.0.2?
7. Is the proxy service running? `ps auwx | grep proxy`

### Mtokwane:

1. Is the WiMAX CPE on? Can you see that there is signal strength on the bottom of the CPE?
2. Is the router on? Log in, run ifconfig and check that that dcw0 and int0 Have an active status.
3. Can you see a tun0 interface on the router? Does it have an IP associated with it, 192.168.255.3? If not can you ping 169.254.0.1 from the router?
4. Is the server on? Check that the server can ping the router, 192.168.2.1?
5. Run Firefox, is the proxy manually set to use the proxy server at Mpume, 192.168.0.1 Port 3128?
6. Mtokwane is reliant on Mpume AND Ngwane, thus you need to do perform the checks mentioned above for both Ngwane and Mpume to help diagnose problems at Mtokwane

## Appendix 5

### If you are failing to access the web browser

First thing to check is are the proxy settings set in the browser?

To get to the settings: edit -> preferences -> advanced -> network -> settings

Check if the manual proxy configuration is set to:

192.168.0.1 Port 3128 and has the "use this proxy server for all" been checked?

If yes, then is the proxy server running on the Mpume server?

Login in as root on the Mpume server and type

```
ps aux | grep squid
```

Is it listed in the output of processes? If not or you are not sure then

restart it anyway, again as root:

```
/etc/init.d/squid restart
```

## Appendix 6

### How to install Nagios

First you need to install the following packages

```
sudo apt-get install apache2
```

```
sudo apt-get install build-essential
```

```
sudo apt-get install libgd2-xpm-dev
```

#### 1) Create Account Information

Become the root user.

```
sudo -s
```

Create a new Nagios user account and give it a password.

```
#!/usr/sbin/useradd nagios
```

```
#passwd nagios
```

On Ubuntu server edition, you will need to also add a Nagios group (it is not created by default). You should be able to skip this step on desktop editions of Ubuntu.

```
#!/usr/sbin/groupadd nagios
```

```
#!/usr/sbin/usermod -G nagios nagios
```

Create a new nagcmd group for allowing external commands to be submitted through the web interface. Add both the Nagios user and the apache user to the group.

```
#!/usr/sbin/groupadd nagcmd
```

```
#!/usr/sbin/usermod -G nagcmd nagios
```

```
#!/usr/sbin/usermod -G nagcmd www-data
```

#### 2) Download Nagios and the Plugins

Create a directory for storing the downloads.

```
#mkdir ~/downloads
```

```
#cd ~/downloads
```

Download the source code tarballs of both Nagios and the Nagios plugins (visit <http://www.nagios.org/download/> for links to the latest versions). At the time of writing, the latest versions of Nagios and the Nagios plugins were 2.10 and 1.4.10, respectively.

```
#wget http://switch.dl.sourceforge.net/sourceforge/nagios/nagios-2.10.tar.gz
```

```
#wget http://kent.dl.sourceforge.net/sourceforge/nagiosplug/nagios-plugins-1.4.10.tar.gz
```

### 3) Compile and Install Nagios

Extract the Nagios source code tarball.

```
#cd ~/downloads
```

```
#tar xzf nagios-2.10.tar.gz
```

```
#cd nagios-2.10
```

Run the Nagios configure script, passing the name of the group you created earlier like so:

```
#. /configure --with-command-group=nagcmd
```

Compile the Nagios source code.

```
#make all
```

Install binaries, init script, sample config files and set permissions on the external command directory.

```
#make install
```

```
#make install-init
```

```
#make install-config
```

```
#make install-commandmode
```

Don't start Nagios yet – there's still more that needs to be done...

### 4) Customize Configuration

Sample configuration files have now been installed in the `/usr/local/nagios/etc` directory. These sample files should work fine for getting started with Nagios. You will need to make just one change before you proceed...

Edit the `/usr/local/nagios/etc/objects/contacts.cfg` config file with your favourite editor and change the email address associated with the `nagiosadmin` contact definition to the address you'd like to use for receiving alerts.

```
#vi /usr/local/nagios/etc/objects/contacts.cfg
```



## 5) Configure the Web Interface

Install the Nagios web config file in the Apache conf.d directory.

```
#make install-webconf
```

Create a nagiosadmin account for logging into the Nagios web interface. Remember the password you assign to this account – you’ll need it later.

```
#htpasswd -c /usr/local/nagios/etc/htpasswd.users nagiosadmin
```

Restart Apache to make the new settings take effect.

```
#!/etc/init.d/apache2 reload
```

## 6) Compile and Install the Nagios Plugins

Extract the Nagios plugins source code tarball.

```
#cd ~/downloads
```

```
#tar xzf nagios-plugins-1.4.10.tar.gz
```

```
#cd nagios-plugins-1.4.10
```

Compile and install the plugins.

```
#. /configure --with-nagios-user=nagios --with-nagios-group=nagios
```

```
#make
```

```
#make install
```

## 7) Start Nagios

Configure Nagios to automatically start when the system boots.

```
#ln -s /etc/init.d/nagios /etc/rcS.d/S99nagios
```

Verify the sample Nagios configuration files.

```
#!/usr/local/nagios/bin/nagios -v /usr/local/nagios/etc/nagios.cfg
```

If there are no errors, start Nagios.

```
#!/etc/init.d/nagios start
```

Login to the Web Interface

<http://localhost/nagios/>

Click on the “Service Detail” navigation bar link to see details of what’s being monitored on your local machine.

## 9) Other Modifications

email notifications for Nagios alerts, you need to install the mailx (Postfix) package.

```
#apt-get install mailx
```

You’ll have to edit the Nagios email notification commands found in `/usr/local/nagios/etc/commands.cfg` and change any `/bin/mail` references to `/usr/bin/mail`. Once you do that you’ll need to restart Nagios to make the configuration changes live.

```
#/etc/init.d/nagios restart
```

## Program listings

Net-monitor script that was added as a plugin to Nagios

```
<?php

    require_once "Net/Ping.php";

    define ('BROADCAST_ADDRESS', /*our broadcast ip*/ "put your value
here");
    define ('MAC_ADDRESS', /*our mac*/ "put your value here");
    define ('SOCKET_NUMBER', /*our socket*/ "put your value here");
    define ('IP_ADDRESS', /*our peer to ping*/ "172.20.56.56");
    $ipAddress="172.20.56.56";
    $mac_Address="00:24:21:9b:d9:d6";
    $socket_Number="9";
    $broad_Cast_Address="255.255.255.255";

    $ping = Net_Ping::factory ();
    function send_Message_ToServer($message) {
        $server= 'localhost';
        echo $message;
        $url = 'http: //localhost/echoServer.php/?message='.$message;
        $content = $message;
        $content_length = strlen ($content);
        $headers= "POST $url HTTP/1.0\r\nContent-type: text/html\r\nHost:
$server\r\nContent-length: $content_length\r\n
\r\n";
        $fp = fsockopen ($server, 80, $errno, $errstr);
        if (!$fp) return false;
        fputs ($fp, $headers);
        fputs ($fp, $content);
        $ret = "";
        while (!feof($fp)) {
            $ret.= fgets($fp, 1024);
        }
        fclose ($fp);
        print $ret;
    }

    function sendMagic_Linux_Packet_for_Wake_on_Lan( $mac){

        $output = shell exec ('wakeonlan '. $mac);
        echo (nl2br($output));
        send_Message_ToServer ($output);

    }

    function sendMagicPacket ()
    {
        $output =system ("wakeonlan 00:24:21:9b:d9:d6");
        send_Message_ToServer ($output);
    }

    function sendMagicPacket_for_Wake_on_Lan($addr, $mac, socket_Number){
        $addr_byte = explode(':', $mac);
        $hw_addr = '';
```

```

for ($a=0; $a <6; $a++) $hw_addr .= chr(hexdec($addr_byte[$a]));
$msg = chr(255).chr(255).chr(255).chr(255).chr(255).chr(255);
for ($a = 1; $a <= 16; $a++) $msg .= $hw_addr;
//send it to the broadcast address using UDP
$s = socket_create(AF_INET, SOCK_DGRAM, SOL_UDP);
if ($s == false) {
    $message= "Error creating socket in sendMagicPacket!";
    send_Message_ToServer($message);
    $message= "Error code in sendMagicPacket is '".socket_last_error($s)."'
- " . socket_strerror(socket_last_error($s));
    send_Message_ToServer($message);
    return FALSE;
}

else {
    //setting a broadcast option to socket:
    $opt_ret = socket_set_option($s, 1, 6, TRUE);
    if($opt_ret <0) {
        $message= "setsockopt() failed, error: " . strerror($opt_ret) . "\n";
        send_Message_ToServer($message);
        return FALSE;
    }
    if(socket_sendto($s, $msg, strlen($msg), 0, $addr, $socket_number)) {
        $message= "Magic Packet sent successfully to ".$addr;
        send_Message_ToServer($message);
        socket_close($s);
        return TRUE;
    }
    else {
        $message= "Failed to send magic packet to ".$addr;
        send_Message_ToServer($message);
        return FALSE;
    }
}

function _ping($netPing,$address){
    if(PEAR::isError($netPing))
        echo $netPing->getMessage();
    else
    {
        /* Number of packets to send */
        echo "address is ".$address;
        $message="Pinging$address\n";
        send_Message_ToServer($message);
        $netPing->setArgs(array('count' => 4));
        $rawData = $netPing->ping($address);
        $packetLoss = $rawData->_loss;
        if ((int)$packetLoss>=2){
            $message =
"firstpingattemptlostmorethan50%ormorepacketsretrying\n";
            send_Message_ToServer($message);
            $rawData = $netPing->ping($address);
            $packetLoss = $rawData->_loss;
            if ((int)$packetLoss>=2){
                $message=
"2nd_ping_attempt_lost_more_than_50%_or_more_packets_retrying ";
                send_Message_ToServer($message);
                $rawData = $netPing->ping($address);
                $packetLoss = $rawData->_loss;
                if
((int)$packetLoss>=2){

```

```

                                $message=
"3rd_ping_attempt_lost_more_than_50%or_more
                                packets ,rebooting ";

send_Message_ToServer($message);

//sendMagicPacket_for_Wake_on_Lan($broad_Cast_Address,
                                // $mac_Address,$socket_Number);

//sendMagic_Linux_Packet_for_Wake_on_Lan( $mac);
                                sendMagicPacket();

                                }
                                else{
                                    //log to server
                                $message =
"3rd_ping_attempt_received_more_than_50%or_more_packets,server_is_now_up!";

send_Message_ToServer($message);

                                }

                                }
                                else{
                                    //log to server
                                $message = "2nd ping attempt
received more than 50% or more packets,server
                                is now up!";
                                    send_Message_ToServer($message);
                                }

                                }
                                else{
                                    //log to server
                                $message =
"1st_ping_attempt_receivedmorethan50%ormorepackets,serverisup!";
                                    send_Message_ToServer($message);
                                }

                                }
                                }

_ping($ping,$ipAddress);

?>

```

