Bringing Internet connectivity to rural Zambia using a collaborative approach

K. W. Matthee
Meraka Institute, CSIR, South Africa
kmatthee@csir.co.za

G. Mweemba, A. V. Pais, G. van Stam
LinkNet, Zambia
{g.mweemba, adrian.pais, gertjan.vanstam}
@link.net.zm

M. Rijken
TNO, Netherlands
e-mail: marijn.rijken@tno.nl

***Abstract* - This paper presents an initiative to bring connectivity to rural Zambia using a collaborative approach. In particular, it focuses on a proof-of-concept Internet service that has been implemented in rural Macha located in the Southern Province of Zambia. The service operates using satellite terminals (for connection to the Internet) and a wireless local area network. The provision of Internet access has enabled local health institutes to operate more effectively and given local people the opportunity to communicate and explore new ideas. It has also created new employment opportunities and generated several projects including a data entry service and a sunflower farming initiative. Being a rural area, several problems hamper progress including frequent electricity outages and the exorbitant cost of bandwidth. International collaboration has been established between LinkNet, the Meraka Institute (South Africa), TNO (Netherlands) and the Global Research Alliance. With its partners, LinkNet addresses the main challenges through applied research and innovation and targets an up-scaling of its activities throughout rural Zambia and beyond.**

I. INTRODUCTION

The digital divide has the potential to exacerbate the already wide disparities between people in society if it is not addressed with due urgency [1]-[7]. Statistics published by the International Telecommunications Union (ITU) show that the entire continent of Africa has fewer Internet users than France alone [8]. Clearly this huge disparity in Internet access is undesirable because it demonstrates that people of different communities do not have equal opportunities to benefit from technology in their daily lives.

Access to telecommunication services such as the Internet has a direct and mutual correlation with the gross domestic product (GDP) per capita of a country [4]. Therefore, telecommunications access strongly influences the financial and social well-being of a population. In developing countries, the vast majority of people (approximately 70% to 85% of the labor force) live in rural areas [9]. For a developing country to increase its productivity and for the populace to enjoy an improved quality of life, it is therefore essential that rural areas are developed to the extent where new opportunities are created and innovations occur [10]. Most rural areas face significant resource challenges such as poor communications, transport, electricity and water supply [10].

The purpose of this paper is to present the work of LinkNet [11], an organisation whose vision is to bring telecommunication services and Internet connectivity to rural areas throughout Zambia. The roll-out of telecommunication services offers rural Zambians the chance to communicate within and outside their villages, creating new employment possibilities for them and addressing the communication needs of a variety of institutions, for example, schools, hospitals and churches.

In February 2006, the LinkNet Master Plan [26] was released with the objective of conveying to potential funders that an investment of $2 million will enable the roll-out of the Internet at 25 rural sites over a period of three to five years, creating the foundation for a nationwide roll-out in 200+ rural sites [26].

In 2004 and 2005, LinkNet rolled out telecommunication services in rural Macha, a village in the Southern Province of Zambia. This successful implementation is a proof-of-concept for further implementation of telecommunication services in other rural areas. In essence, the proof-of-concept deployed key telecommunication infrastructure and basic information technology services (e.g. e-mail and Internet browsing) for the people of Macha. During 2007, a proof-of-reproduction is being implemented in Mukinge, a village in the North Western Province of Zambia.

This paper focuses entirely on the proof-of-concept in Macha village including the technical solution implemented, the benefits and challenges experienced and the fruitful collaborations with other organisations. In addition, an independently conducted qualitative study on Internet usage within the village is discussed.

The geographic, social and economic context of Macha village is presented in Section II. An overview of the Internet provision in Macha is described in Section III, while the technical details of the implementation are discussed in Section IV. Section V outlines international collaborations that have been established. These collaborations have led to the successful implementation of a wireless mesh network in Macha. In Section VI, the business case for Internet connectivity in Macha is discussed. Section VII discusses the pressing technical challenges in providing the Internet service

in Macha. Section VIII presents three case studies to demonstrate the socio-economic benefits resulting to the Macha community as a result of Internet access. Results from an independently conducted qualitative study on Internet usage within Macha are discussed in Section IX. Section X summarizes the future work still to be conducted, while the conclusions of the paper are presented in Section XI.

II. CONTEXT

Macha is located in the Southern Province of Zambia, 75 km from the nearest town of Choma and 350 km by road from the capital city of Lusaka [26]. Fig. 1 shows the location of Macha on a map of Zambia. The topography of the area is somewhat undulating, primarily open savannah woodland averaging 1,100 meters above sea level. The climate is tropical with a rainy season that runs from approximately late October to early April.

The Macha area is populated by traditional villagers, primarily members of the Batonga tribe, living in small scattered homesteads which usually consist of one extended family. There are no commercial farmers or industries in the area. While much of the population is stable, younger adults move to and from the urban areas of the country. The primary livelihood is subsistence farming with maize being the main crop. The staple diet is cooked maize meal supplemented with peanuts, sweet potatoes and leafy green vegetables [26].

There is an estimated population of 135, 000 (c. 2007) within an approximate 35 km radius around Macha. Overall population density in this area is 25 per square kilometer and 50% of the population is under 12 years old. Other specific data for the local population are not reliable, but country-wide the crude birth rate is 49.5 per 1,000 people with an infant mortality of 107 per 1,000 live births. Average life expectancy at birth is 39 years due to the prevalence of HIV/AIDS [26].

The average income for a person in the village is $1 per day. A bus trip to the nearest town of Choma costs approximately $7 and it takes about two hours to travel the 75 km distance. The money spent on this journey equates to several days' salary for a person living in Macha [26].

Macha has very limited infrastructure. There is a mission hospital, medical research institute and community centre. Clearly, the health institutions require and expect high quality telecommunication services to be able to offer high quality and efficient health care. Only dirt roads link Macha to other villages and towns. Electricity is available to only the privileged few. Moreover, the supply is unreliable especially during the rainy season when several outages can occur within a single day [26].

III. OVERVIEW OF INTERNET PROVISION IN MACHA

LinkNet provided Internet access in rural Macha in 2004. Prior to this, the only forms of communication in Macha were by an unreliable high frequency (HF) radio link that enabled short messages (300 symbols per second) to be sent to/received from other towns and a very high frequency (VHF) system for voice communication to Choma, the nearest town. Before 2004, Macha had only a handful of 'stand-alone' computers and these were not connected to the Internet [26].

There are no fixed lines or optical fibres connecting Macha elsewhere as telecommunication operators do not view this as a viable business opportunity. Prior to the end of 2006, mobile phone services were not available in Macha.

The successful implementation of telecommunication services and the Internet in Macha was based on four key enablers [26]:

- A holistic approach involving all the stakeholders including health institutions, schools and community members;
- Training of local people for daily IT operations and on-site support;
- Affordable technology customized to the local environment and;
- Central training and implementation at the LinkNet Centre of Experience at Macha.

The key to the success in Macha was a holistic approach involving all the stakeholders including government, the local community, local institutions, and donor organisations. In 2007, after just three years of operation, there are in excess of 100 computers in Macha, 200 local people have been trained in basic computer literacy, ten locals from Macha have been trained as IT technicians and more than 65 new jobs have been created [11]. The IT technicians are not only using their skills within Macha but also contracting their services to institutions in urban areas, bringing in much needed revenue to their families. Additionally, the community has provided data entry services (of thousands of documents) to a company in the developed world. The provision of access to the Internet, coupled with a solid supporting structure, has shown that the local people can empower themselves to improve their lives and create new opportunities.

The technical solution for implementing the Internet is simple and customized to the needs of the community – the infrastructure technology has been chosen so that it is as cheap and as suitable as possible to the local conditions. In summary, the technology includes very small aperture terminal (VSAT) satellite connections to the Internet, a mains power supply augmented by a small scale power supply, a wireless local area network connection for PCs, a network server and communications tools/PCs for training purposes [11].

The up-front investment required for the implementation in Macha was approximately $120,000 which was obtained mainly from an international partner of the medical research institute and donor organisations. With the creation of new jobs, the income generated from outsourcing services and the income generated from the village itself (e.g. from the local medical research institute and hospital), the LinkNet operation in Macha was sustainable after just two years [11].

Applications are being developed to meet the needs of the local community in Macha. These include e-learning systems for students in the community (for which an implementation strategy has been developed [12]) and e-health applications used by doctors in the local hospital. The provision of Internet access has also resulted in 'spin-off' benefits through which local people have demonstrated that they can independently use the Internet for meaningful and relevant purposes, thereby empowering themselves [21] [24].

IV. TECHNICAL SOLUTION

The technical solution implemented in Macha consists of a wireless local area network (WLAN) that is connected via VSAT satellite connections to the Internet. Computers and other user devices connect to the wireless network to obtain access to Internet services. Wired connections are rarely used because they require more installation effort and are sensitive to physical damage. They are also susceptible to lightning damage.

Fig. 2 shows LinkNet's current network topology in Macha. The network consist of two VSAT satellite connections, an IT room with a number of servers, switches and routers, and a three layer WLAN (IEEE 802.11g) network to share the Internet connection throughout the community. Each layer uses a unique radio channel to prevent interference with other layers. The top layer of the WLAN network, indicated in Fig. 2 by dashed lines, is the wireless *wide area backbone* that interconnects several wireless *local area backbones* in the middle layer. The *local area backbones* are formed by mesh clusters (indicated by routers with red labels in Fig. 2). The bottom layer is the clients' access layer with hotspots, not shown in Fig. 2. Each of the mentioned network elements are discussed in more detail below.

A. VSATs

Two VSAT satellite connections provide Internet connectivity to the community in Macha. The first of these is a shared (1:8) C-band VSAT connection with a maximum downlink speed of 1,024 Mbps and a maximum uplink speed of 256 kbps. This VSAT has a committed information rate of 128 kbps on the downlink and 64 kbps on the uplink. The second connection is a Ku-band VSAT connection, which is a shared (1:13) VSAT with a maximum downlink speed of 512 kbps and a maximum uplink speed of 128 kbps. This VSAT does not have a committed information rate. Two VSATs are needed for redundancy as VSAT connections go down intermittently.

The problems experienced are often related to the equipment itself and are caused by power instability and bugs in software upgrades. Furthermore, the bad roads take their toll on equipment, with more than half of the computer hard disks dead on arrival or failing. Repairs may take up to several months as components are often not available locally and communications are hampered when the communication channel is severed. Experience shows that these shared connections often suffer from traffic overload leading to congestion (low throughput and long delays). The Ku-band VSAT has practically no connectivity during office hours as it does not have a committed information rate. The monthly fees for the two VSAT connections total nearly $1,700 per month. Generally stated, the exorbitant cost for bandwidth and the poor network performance are frustrating the development of rural areas in Africa.

B. IT Room

An air-conditioned IT room hosts a number of standard PCs, routers and switches. The servers are used to provide the following services: gateway, traffic shaping, Domain Name System (DNS), file server, backup server, web server, mail server, authentication and billing. Also the network performance is monitored from this room with the help of some basic network monitoring services. Open source software, produced through the innovative spirit of the large open source software development community, minimises costs and prevents vendor lock-in.

Administration of network management and customer relation management is all done on the Intranet by using a content management system called Drupal. Network management remains a challenge as the level of IT expertise of most LinkNet employees is still only basic.

A major problem is the instability of the power grid. Regular outages and high voltage spikes damage the power supplies and hard disks of the computers. Power supply backup using batteries is available, but has insufficient quality. Good information and communication technology (ICT) equipment is difficult or impossible to obtain in Zambia.

C. Wide area backbone

The *wide area backbone* interconnects the different *local area backbones* and the gateway server in the IT room connected to the VSAT connections. In cooperation with the Meraka Institute of South Africa [13] and TNO of the Netherlands [14] (discussed in Section V), LinkNet is presently working on the development of a mesh network topology with multi-radio routers.

For the time being, however, locally available outdoor wireless single-radio routers with built-in directional antennas are used. These outdoor units create point-to-point bridges from a non-routing switch in the IT room to each of the *local area backbones*. Different channels are utilised to prevent interference between the different wireless units, but as there are only three non-overlapping channels available in the 2.4 GHz band, this is a challenge. Physical separation of the antennas is implemented to decrease the interference. Antennas are mounted outdoors on masts or rooftops to create a reliable line-of-sight radio link.

D. Local area backbone

The wireless local area backbones interconnect all buildings

in a local area. A local area is typically one customer such as the hospital, the medical research institute, the community centre or a group of individual houses.

The local area backbones use a mesh network topology. A mesh network is a multi-hop wireless network that maintains communication by hopping from node to node until a destination is reached. It is auto-configuring and self-healing and provides reliable multi-path connections between nodes in the mesh.

Mesh networking provides many benefits to rural communities that wish to become connected. It is a reliable, easy-to-deploy infrastructure with a significantly lower cost than alternative solutions [27]. Members of these communities can install and operate their own networks.

Linksys WRT54GL routers [28] with standard omni-directional antennas are mounted indoors. All mesh routers in this backbone use the same channel. Freifunk firmware running the Optimised Link State Routing (OLSR) mesh routing protocol [15] provide the mesh functionality, configured according to the do-it-yourself mesh guide [16] developed by the Meraka Institute. The transmit power of each router is tuned to minimise the interference between routers in this layer.

E. Clients

Desktop clients connect via a cable to the Ethernet interface of the mesh routers in the local area backbone. The mesh routers run Dynamic Host Configuration Protocol (DHCP) on the Ethernet interface to allocate IP addresses dynamically to the clients. Wireless access directly to the wireless mesh backbone is not supported as it significantly lowers performance in a single-radio mesh node. Where wireless access is needed, a wireless access point is connected to the Ethernet interface. This access point, often a Linksys WRT54G router with DD-WRT as firmware, is configured in bridge mode and forwards the DHCP-allocated IP addresses from the mesh router to the wireless clients.

V. INTERNATIONAL COLLABORATIONS

The Meraka Institute [13] is a South African national ICT research centre managed by the Council for Scientific and Industrial Research (CSIR) [17]. The Institute aims to make a substantial contribution to connecting the 450 million people in rural Africa through research, development and technological innovation, either directly or in association with the Global Research Alliance (GRA) [18], universities, industry, and other research institutes. The GRA is the alliance of nine of the world's leading knowledge and technology research organizations. The Meraka Institute has a research mesh network deployed in Pretoria where it is used by staff. It also implemented a community mesh network in Peebles Valley near White River in Mpumalanga, South Africa, connecting various community sites including an HIV/AIDS clinic, a hospice, other administrative buildings and the homes of community members. The Meraka Institute also has a 49-node mesh network lab where it conducts mesh protocol research.

TNO is the Netherlands Organisation for Applied Scientific Research [14]. TNO's aim is to strengthen the innovative power of industry and government. Next to its main activities, TNO strives to contribute to the Millennium Development Goals [19] through its membership of the GRA and its corporate program on development cooperation, in which LinkNet has been a partner since 2006. TNO supports LinkNet through knowledge transfer and technical innovations, creating partnerships for implementations, and by studying the usage of ICT services in rural areas.

In February 2007, Gertjan van Stam and Adrian Pais of LinkNet, Gerard van Oortmerssen of TNO, and a delegation of the Meraka Institute first met during a visit hosted by the GRA at the CSIR.

The Meraka Institute became aware of the efforts within LinkNet to implement mesh networking as a more reliable alternative than conventional wireless LAN (WLAN) to extend Internet access to communities in rural Africa.

Urged by LinkNet's need for support, the Meraka Institute developed a do-it-yourself (DIY) mesh guide [16] called "Building a rural wireless mesh network." It explains how to plan, configure and deploy a wireless mesh network. It is based on the Freifunk mesh firmware [20] (an open source distribution that uses the Optimized Link State Routing Protocol (OLSR) [15]).

The content of the DIY mesh guide was presented during a hands-on training workshop attended by LinkNet and TNO and hosted at the Meraka Institute in June 2007. The LinkNet team also visited the Peebles Valley community, mentioned earlier, where a mesh network was implemented in 2005.

The Meraka Institute visited Macha and Mukinge in July 2007 to gain firsthand experience of the impact of Internet access in these communities. It was also valuable to see the challenges faced by LinkNet in terms of rural ICT infrastructure provisioning in Zambia. Some of these challenges included the unreliable electricity supply, bad road infrastructure, lack of air conditioning and dust. These factors naturally translate into technology research challenges.

Within one week after the workshop, the LinkNet team was able to set up a mesh network in the rural settlement of Macha in Zambia's Southern Province, providing wireless Internet connectivity to ten buildings including the local hospital. Implementation challenges initially experienced were resolved through cooperation between LinkNet, the Meraka Institute and TNO and led to improvements in the mesh guide.

The signing of a Memorandum of Understanding (MoU) between LinkNet and the Meraka Institute on 17 August 2007 was another significant step towards the creation of low-cost, wireless connectivity in Africa. The purposes of the MoU are to:

- co-operate in research at LinkNet sites;
- create broad awareness of the needs for Internet

access in rural Africa;
- strive for development and publication of open source solutions for deployment in Africa;
- develop a Center of Experience on rural ICT development and training in Zambia; and
- develop research projects to gain a better understanding of realities in rural Africa.

The technology research and development roadmap drafted by the Meraka Institute will address the following requirements:

- to allow the mesh network to auto-configure fully and thereby make the mesh equipment easier to deploy;
- to allow radios in the mesh nodes to select the best frequency and thereby reduce interference and increase throughput;
- to develop multi-radio mesh nodes that will obtain higher throughput; and
- to reduce energy consumption to allow the mesh nodes to operate on batteries and solar power thereby providing a more energy efficient, sustainable solution.

VI. Business Case and Sustainability

LinkNet has developed a Master Plan, including financials, which is published on its website [26]. The financials describe the cost of a rural implementation, including a LinkNet Resource Container at $65,000 per implementation, and the operation of a rural implementation for a period of 10 years. For large rural sites like Macha and Mukinge the operation, including maintenance services, is estimated at $108,000 over 10 years. The business plan expects financial self-sustainability at Macha and the other LinkNet sites after approximately three years. External funding provides a financial kick-start. The financials in the business plan contain profit and loss, cashflow and balance sheet information.

VII. Technical Challenges

Working in rural areas has challenges not often encountered in urban areas. For example, a large number of computers are damaged by power interruptions, high temperatures and dust. The power problem is just one of the many problems that need further research. Other problems are frequent hard disk failures, the high cost of the VSAT connections for Internet services, bandwidth and network management and the lack of a viable billing system.

Some of these problems require unique research that will lead to long-lasting and cost effective solutions. Long term, on-site research will clarify the real problems and provide answers that are suitable for the environment.

Analysis of each individual challenge will illustrate how it affects the daily operations of ICT infrastructure at LinkNet.

A. Electricity problems

Rural areas are prone to power interruptions. This causes damage to computers, the Local Area Network (LAN) as well as the Wireless LAN.

The most affected equipment is:

- Power supplies
- Hard disks
- Routers
- Motherboards, and
- Memory chips.

High temperatures and frequent outages shorten battery life of uninterruptible power supplies (UPSs) considerably. Replacement batteries are often not available in the country. Because of this, car batteries have been used to replace the original UPS batteries. However, the UPSs were not able to fully charge the car batteries. This is presently being investigated further.

Hard disks do not last long in a rural area such as Macha. Many factors contribute to this problem, including damage during transportation and power failures. The high temperatures and dust are also likely causes of hard disk failures.

As most equipment is re-furbished and old, affordable hard disks are needed but difficult to source.

B. VSAT connection cost

People in rural areas normally do not earn as much as people in urban areas. Thus, they have less money to spend on leisure. For some, the Internet is seen as such a service; just another form of leisure. Thus, they would not even dare to invest their money in it. However, given a chance, these very people are willing to explore and learn what ICT is all about provided they feel it is affordable. Locals often come to the Vision Internet Café (an Internet Café incorporated by LinkNet Zambia) with the desire to use the Internet for the first time. When the charges (per minute) are made known to them, they choose not to use the service. They do this not because they do not want to, but because they find it unaffordable.

Unfortunately, the cost for an Internet connection (which is via VSAT connections) is more expensive in rural areas than in cities. Cities normally have higher densities of subscribers, which in turn reduces the effective cost for each Internet subscriber.

In Macha, the total throughput for the entire village from the two VSAT connections is approximately 1.5 Mbps, costing an exorbitant $1,700 per month. By contrast, in developed countries, a single user might enjoy as much as seven Mbps using an ADSL connection for only $40 per month.

This raises an interesting question: how can the connection costs of a satellite link be reduced to cater for communities

that cannot afford the high costs that are currently demanded from rural areas? Only when low cost connectivity is available will we be able to say, 'Internet is ...information for all.'

C. *Bandwidth and network management*

Monitoring of the Internet Gateway, LAN and WLAN is a crucial task of a network administrator. ICT technicians/administrators should know the status of the network based on information that is gathered from the network. The relevant information can help ICT experts employ ways that would help improve the quality of service to the customer. It can also lead to a more secure and stable network.

However, finding viable tools to help monitor the current network setup at Macha is not easy. Most open source tools require a level of expertise that LinkNet has not yet reached.

Is a cost effective and long lasting solution, which local people can manage, possible? How about traffic shaping for the entire network? How can specific users be assigned maximum bandwidth limits? How about firewalling and SPAM filtering?

These are areas that require special attention to find viable solutions for networks like the one currently existing in Macha.

D. *Billing for services offered*

In order to maintain services, customers should contribute to the overall development and operation of the service by paying for what they use.

Finding a lasting, accurate and stable solution is important as simple mistakes can ruin the relationship between customers and the service provider. No customer wants to be billed wrongly; a customer wants to pay for what he/she has used.

An accurate system that is able to determine how much the customer owes is essential. A pre-paid system is especially useful in rural areas as customers can pay in advance for what they will use. If a customer exceeds the limit of allowable access (e.g. volume of download or the time of usage), the system automatically cuts the customer from the service after a warning has been communicated to him/her.

VIII. SOCIO-ECONOMIC BENEFITS

LinkNet sees the provisioning of Internet connectivity as a pre-requisite for the development of rural areas. Subsequently, after introduction of the Internet to the Macha community, several unforeseen innovations occurred. These innovations have led to significant socio-economic benefits. This section presents three case studies on tangible benefits that have been observed as a result of Internet connectivity.

The first case study discusses the introduction of sunflower production in Macha, while the second case study discusses a data entry service provided to a company in the United States of America (USA). The third case study discusses the tangible benefits of using ICT in the fight against HIV/AIDS and other infectious diseases.

A. *Sunflower farming*

Only a few months after the introduction of the Internet to Macha, a farming innovation occurred as a direct result of access to new information and ideas through the Internet [21].

Fred Mweetwa is a young man who was born, grew up and educated in the rural Macha community. At his workplace, the Vision Community Centre, Macha, he has access to the Internet [21]. In mid-2005, only a few months after the Internet was made available to the Macha community, he independently searched it for new ideas on farming and came across information on sunflower production at two websites [22], [23].

Based on the information gathered from the Internet, Fred started preparing his land for sunflower production. This land is located within the Macha chiefdom in an area where title deeds are non-existent. It has been used by Fred Mweetwa's family for many decades. Previously, only maize or peanuts were grown in these fields, with varying yields.

In December 2005, a total of 20 kg of sunflower seeds were bought and planted in two fields of approximately 25 by 100 meters for the 2005-2006 growing season. Fred employed ten people on a part-time basis to weed and tend the plants in line with specific information given on the Internet [21].

In May 2006, Fred Mweetwa and his team harvested the sunflowers, resulting in 70 bags of sunflower seeds, each with a weight of 50 kg. These seeds were then pressed to yield approximately 3 liters of cooking oil per 20 kg of sunflower seeds. The oil was then bartered for maize to feed the entire Mweetwa family during 2006. This family consists of the parents, four children and five other relatives. The barter rate was 750 ml of oil to be exchanged for 10.5 kg of white maize [21].

Some cooking oil was sold for ZMK 5,000 (equivalent to $1.50) per 750 ml. This money was used to cover investments for the next growing season in 2006-2007. The demand for sunflower cooking oil in the community has noticeably exceeded the supply [21].

After pressing the sunflower seeds to extract the oil, sunflower cake (residue) remains. Fred uses this cake as supplementary feeding of his fifteen pigs and also sells some of it in the nearby town, Choma, for ZMK 12,000 per 10 kg.

During the farming season of 2006-2007, sunflower production increased ten-fold. Further information about the sunflower farming and a business case can be found in [21].

B. *Data entry services*

The availability of human resources coupled with the availability of the Internet, the drive to explore new business opportunities and the involvement of local community leaders has led to an innovative project in which the Macha

community provided data entry services for a company based in the USA [24].

The project, branded the "Macha Conversion Project", was developed for a USA-based company. The project involved capturing information from 700,000 documents into a database [24]. The work was done entirely through the Internet. The documents were retrieved from the company's server in the USA using a web browser. The project was conducted in two separate phases [24]:

- The first phase was a 'test phase' to demonstrate whether the people in Macha could provide the desired quality of work.
- The second phase was the execution of the remainder of the work.

Project management in Macha was performed by two people from within the local community, who were trained with relevant skills and knowledge. Approximately 20 workers were involved in entering the data, working in shifts for 24 hours per day [24].

After a successful first phase, in which 383,838 documents were entered by 20 workers, the USA-based company decided that all the documents should be done in Macha. The project ended after all 700,000 documents were captured. During the execution of the project, the Macha project team published performance graphs in a web-based Content Management System (CMS) so that all stakeholders could assess progress on a daily basis [24].

This project has brought hope to and raised aspirations among the people of Macha. School leavers gained invaluable work experience and brought in much needed revenue to Macha. The project demonstrates that rural Africa can competitively do business with other parts of the world [24].

C. Fight against HIV/AIDS and other infectious diseases

The fight against HIV/AIDS can be augmented with improved quality of HIV care, prevention, and treatment through locally sustained deployment of health communication, clinical, and management information systems. These services are essential for quality, sustained care in poorly connected remote locations.

This improvement has been achieved though the deployment of the ICT services in Macha's hospitals and the community, increasing the number of people receiving care and preventative services, and improving the quality and sustainability of the health system.

Tangible results in clinical care

The proof-of-concept in Macha Rural Hospital has shown that telecommunication services are crucial for a remote health care site with an anti-retroviral therapy (ART) clinic.

Since its inception in early 2005,

- approximately 2,000 HIV positive people visit the ART-clinic regularly; and
- approximately 1,000 people have been supported with ART.

However, many times more people with HIV receive palliative care from the hospital. The sheer possibility of adding such numbers to an already stretched hospital schedule of activities necessitates the introduction of the improved ICT infrastructure to assure that efficiency and quality are maintained.

In Macha Rural Hospital, at each stage of implementing, sustaining, and improving the quality of HIV/AIDS care, the availability of ICT services and expertise has been essential and is often crucial. This is equally true in the dissemination of reports on HIV/AIDS care provisioning.

As a result of this capacity in Macha, several focused expert visits were arranged with direct results. The implementation of CD4 testing equipment would have been considerably delayed if communication was not possible. Locally trained ICT experts support electronic patient information recording systems to improve ART treatment, support and referral systems. Locally identified and trained rural community members are instrumental in data entry and in keeping ICT hardware and software going on a daily basis in these more logistically challenged remote areas, where 'information highway' access is often the only practical road.

In addition to these primary applications, less extensively trained and less experienced clinical talent has been able to tap into global health expertise via telecommunication services resulting in information-based decisions, thereby improving the quality of care and treatment. Additionally, it appears that simple access to e-mail communication in remote locations is beneficial to the retention of mid-level providers assigned to work in remote areas.

Furthermore, in Macha the availability of communication with the outside world (and particularly, Lusaka) assures a steady supply of HIV/AIDS medicine given the tedious logistical process which is dependent on timely communication and interaction. On several occasions in past years, a steady flow of medicine could only be maintained by direct intervention, in a manner only made possible through the ICT infrastructure.

IX. QUALITATIVE STUDY OF INTERNET USAGE WITHIN MACHA COMMUNITY

The Internet in Macha is provided to institutions such as the medical research institute, the hospital and schools. Individuals can access the internet in a public internet café or by applying for a connection at home. Connections at home are mostly used by teachers, hospital staff, researchers and international visitors staying in the guest houses. A study on Internet usage revealed that the most prevalent use of the Internet is personal communication via e-mail and chat. Other usage by community members includes e-learning, buying goods such as second-hand cars from Japan, improving knowledge on agricultural techniques and acquiring education

material.

Interviews with local community members were conducted in a study on the use of Internet in rural Zambia [25]. Some of the findings of these interviews are discussed in the following sections.

A. First use of the Internet

The interviews started by asking people to tell the interviewers their story about the first time they used the Internet. In the African culture, where people are accustomed to storytelling, this approach worked very well. The participants who have used the Internet started using it between 2003 and 2005. Most participants first used the Internet in the Internet cafe at the Vision Community Centre in Macha; others used it in Choma, Lusaka or abroad. Some people received help in getting started from their friends, children or other relatives; others were assisted by people working in the Internet cafe. The desire to send e-mails to relatives and friends was a strong trigger to start using the Internet.

"My enthusiasm to use Internet was driven by a Canadian young man who stayed with me and encouraged me to open up an e-mail address so that we could communicate when he leaves for Canada. This prompted me to open an e-mail account."

Education is another important trigger to start using the Internet. Several participants looked up information for their assignments, for example, for the Zambia Open University. Others follow e-learning courses at institutes abroad.

"I am studying at Zambia Open University. Internet has really helped me to acquire information for my school assignments as libraries are very scarce here."

Chatting was another trigger.

"These guys were doing a lot of chatting with people from Australia, America, New Zealand, people from all over the world. They would type and then click on enter and those guys would reply immediately. When I was watching, I was very surprised as to how it worked. So they also opened an account for me at Yahoo and I started chatting and also sending e-mail."

B. Continued use of the Internet

After their first introduction to the Internet, all participants continued to use it. Some do so regularly. They browse websites to look up information for studies, how to use Linux, how to repair cars, farming, news reports and weather reports (used by the airport manager). People buy books, school materials and even look up prices and buy second-hand Japanese cars. Beside information retrieval, they establish new contacts with people all over the world not only for fun, but also to exchange information and consult experts on certain topics such as those mentioned above. Also, some participants use the Internet to send reports to donors and supporters of schools living in other countries.

"Since then, I use Internet twice a week; I do this after knocking off from work".

"Apart from studying online, I also use Internet to communicate with my children based in the United States of America and friends throughout the world".

"I am still using the Internet on a daily basis; this gives me an opportunity to communicate with my friends in Germany".

Others do not use the Internet very frequently, mainly because of the distance between their homes and the Vision Community Centre or any other place where the Internet is available. All these participants expressed the desire to have the Internet at their homes or workplaces.

"At the moment I do not use Internet regularly … it is a 30 minutes' walking distance to the community centre where Internet is accessible. My wishes are to have Internet connectivity at our school but the major barrier is the absence of power at our school."

C. How the Internet changes lives in rural areas

Unanimously, participants state that the Internet has changed their lives. For some the impact is still small, but for others the Internet has greatly changed their lives for the better.

"To me, Internet has changed my way of life because I would not be the way I am now without it. I am now able to study online and also communicate with friends around the world."

"Internet has changed my life in terms of communication because, before Internet arrived at Macha, I used post messages through the post office; it took time to receive a reply even if the information was urgently needed."

Interestingly, the Internet has also had an impact on the lives of those who themselves have not yet used it. For example, students receive better quality information from teachers who use the Internet and farmers learn new things from other farmers who use the Internet:

"In 2005 I was searching for conditions necessary for sunflower growing. I found the information in the Internet. So I went to buy the seeds and planted the sunflowers. Last year I had a successive harvest and this year I'm looking forward to a successive harvest as well. It changed me as an individual, but also the community. One of my friends and also a teacher

started growing sunflowers and others have started planting the sunflower. They followed my footsteps."

In this case, Internet access led to the introduction of sunflower farming [21] and, as mentioned, this has turned out to be an effective way to generate income.

X. FUTURE WORK

Experiences in Macha and other rural areas have shown that ICT plays a pivotal role in the development of a rural community. Such development can only take place when all stakeholders participate in the process. LinkNet has ensured such participation as it is set up as a co-operative and open society, owned by local rural institutions, and located in - and thus part and parcel of - the rural environment.

Local people from rural areas are leaders in LinkNet. They are trained to implement and maintain their local networks. Further study on the drivers, motivators, and critical success factors is needed. LinkNet is committed to do this, and provide for a stream of reports on its website [11], initiated from rural Africa.

The next step is a proof-of-reproduction, further strengthening, extending and solidifying relationships. African development will be fostered and local program management implemented. To solve the major constraints mentioned, pinpointed and well defined projects will be set up in 'the living laboratory' that Macha is providing. For this, Meraka, TNO, other GRA members and international donors have pledged their support.

Technical and operational research based and executed in African rural areas is sought, as only then a complete understanding of the environment can be gained [6].

LinkNet aims for innovations that are usable, originating from within the African rural areas. For instance, one could look at the current show-stopping status quo on bandwidth prices. Innovative ways of addressing bandwidth problems, and its financing are in short supply. Africa needs dedicated, good quality and free Internet connectivity, at least on-par with empowered Western societies. This is especially needed for special interest groups in health, education and community development. The benefits of free Internet access for the development of Africa could outstrip costs. Studies of technology and other hurdles in rural areas can result in a better understanding of local conditions and ensure connectivity reaches those who need access the most. Considering a single problem, such as the HIV/AIDS pandemic, innovative financing options are being envisaged.

All these initiatives are supported by committed, international organisations like the Meraka Institute from South Africa [13], TNO from the Netherlands [14], and GRA [18] partners around the world.

XI. CONCLUSIONS

LinkNet has provided Internet access in rural Macha since 2004. The technical solution is simple and customized to the needs of the community – the infrastructure technology is low-cost and appropriate for the local conditions. It includes VSAT satellite connections to the Internet, a mains power supply augmented by a small scale power supply, a wireless mesh network, a network server and connections for PCs.

Internet in Macha is provided to local research institutions, the hospital and to schools. Individuals can access the Internet in a public internet café or by a connection at home. The most important usage of the internet is personal communication via e-mail and chat services. Furthermore, the provision of Internet connectivity to the Macha community has yielded several innovations that were not anticipated when the Internet was first introduced. These innovations have led to significant socio-economic benefits.

The successful implementation of telecommunication services and the Internet in Macha was based on four key enablers:

- A holistic approach involving all the stakeholders including health institutions, schools and community members;
- Training of local people for daily IT operations and on-site support;
- Affordable technology customized to the local environment and;
- Central training and implementation at the LinkNet Centre of Experience at Macha.

Working in rural developing areas presents problems that are not often encountered in other parts of the world. The main problems are power instability and the damage it causes to electrical equipment, malfunctioning computer hardware due to transport and harsh local environmental conditions, absence of local hardware suppliers and exorbitant satellite connectivity costs.

International collaboration has been established between LinkNet, the Meraka Institute in South Africa, TNO in the Netherlands and the GRA. With its partners, LinkNet is addressing the main problems through applied research and innovation and it targets an upscaling of its activities throughout rural Zambia and beyond.

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Fig. 1. Map of Zambia with Macha in the Southern Province.

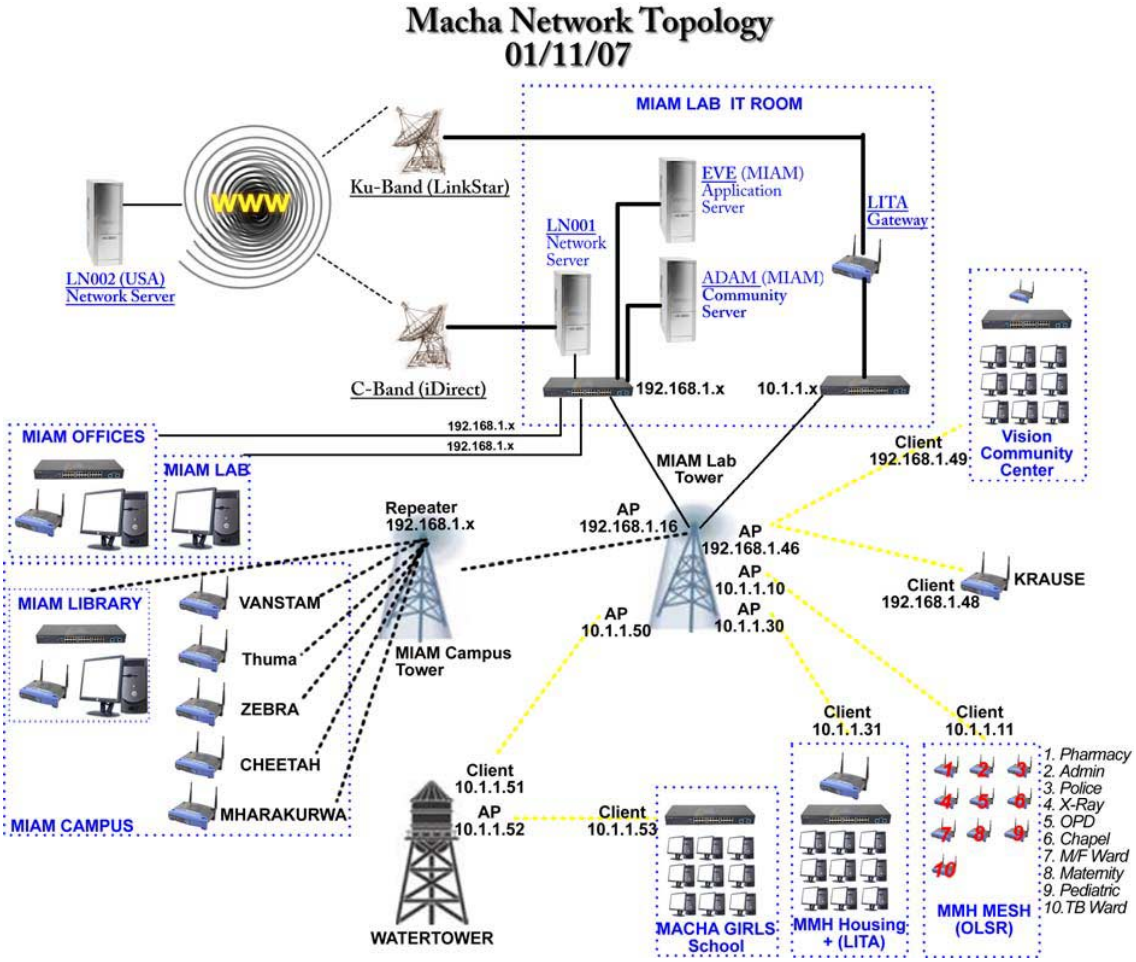

Fig. 2. LinkNet's network topology in Macha, Zambia.