Serengeti Broadband

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ABSTRACT

This paper presents a broadband island defined by a fibre-optic communication network between Bunda and Serengeti, two rural districts in the Mara region in northern Tanzania. The purpose of the network is to facilitate creation and sharing of information at government institutions. The network is also expected to create jobs and entrepreneurial activities in these under-served areas

The network is comprised of an optical fibre backbone and wireless local area networks operating in license-free spectrum as access networks. The fibre is currently terminated at three locations. VLAN-capable Ethernet switches with long range optical transceivers provide backbone transmission as well as fibre access. To minimize costs, routers and servers in the network are all based on standard PC hardware and Free Open Source software. The infrastructure is operated under an Open Access regime, other ways of resource sharing like virtualization at the link; network and application layers are explored.

Although the broadband island defined by the fibre has a narrowband VSAT connection to the Internet, the focus on the services provided in the network is local, focusing on e-government, education, healthcare and support to local entrepreneurs.

Categories and Subject Descriptors

C.2.1 [**Computer Communication Networks**]: Network Architectures and Design – *wireless communication, network communications, network topology.*

General Terms

Documentation, Design, Economics, Experimentation.

Keywords

Networks, Network Design, Broadband Communication, Rural Networks.

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1. INTRODUCTION

ICT4RD, ICT for Rural Development in Tanzania, is a four year program involving key actors in public- private partnerships [2]. The objective of the program is to develop and test a scalable methodology for providing sustainable broadband connectivity to rural areas. Some external funding is made available by Sida and managed by a management committee with representatives from COSTECH [10], DIT [11] and KTH [12].

The approach to achieve sustainability is to motivate infrastructure investments (Capex) by focusing on basic public services and at the same time stimulate usage in all sectors to find users willing to pay to cover the operational costs (Opex). The targeted users include public sector from local government, education, health, environment and support to local entrepreneurs.

There is a lot of optical fibre cable being deployed in Tanzania as part of other infrastructure projects, along power lines, pipelines, railways, etc. The ICT4RD program strategy is to develop agreements with different fibre owners to utilize redundant infrastructure wherever available.

The program has initially made agreements with two fibre cable owners:

- Ministry of Water to use a fibre pair in the metering network of their Wami river water distribution project in the Bagamoyo district, Cost region;
- The power utility company TANESCO [8] to use a fibre pair in a 134 km long fibre cable deployed under the rural electrification program in their medium voltage (33kV) line between Bunda and Mugumu, the district capitals of the Bunda and Serengeti districts in the Mara region, northern Tanzania. The fibber is installed in the optical power ground wire (OPGW) and accessible every fifth km. The fibre line passes through 15 villages.

These networks have different challenges involved in accessing the fibre. In the Wami network, there is an optical distribution frame (ODF) in each pump station along the pipeline where the fibre can be accessed and equipment placed, while in the Serengeti network such an environment is available only in one end of the fibre cable. These challenges are discussed later.

This paper is unique in a sense that it describes an advanced network in rural areas. Thus, this paper offers two contributions: First, we describe the design of the *Serengeti network and discuss* how the design meets the objectives of the ICT4RD program. We provide details on the network layout, detailing the network nodes, antennas and masts and other hardware used.

Second, we report on the deployment of the different parts of the network where a number of challenging practical issues are addressed. We describe the problems behind these challenges and how they were solved. The lessons learned provide fruitful insight that can be used as guidelines for the planning and deploying networks of similar objectives.

The paper is organized in seven sections: Section 2 is about the network objectives. Section 3 describes the design challenges. Section 4 is about implementation challenges. Section 5 is on network evaluation; section 6 contains our conclusions while section 7 provides references.

2. NETWORK OBJECTIVE

There is no reason to assume that communication needs in developing regions are different to the needs in developed regions. The goal is thus to provide all users with access to communication services at a capacity that is not a bottleneck. The superior infrastructure from a capacity point of view is no doubt optical fibre. There is little legacy copper network in Africa in general and none in the regions discussed in this paper. The alternatives to optical fibre are mare terrestrial wireless for shorter links (line of sight) and VSAT for long-haul links. Mobile users of course benefit from wireless access while backbone links and servers benefit from the higher capacity of optical fibre. The communication market in Serengeti is not yet developed, due to lack of affordable access. There is, however, a large potential for development if only the process can be started. Due to lack of interest from commercial actors, a focus on basic public services is necessary to motivate basic infrastructure investments and open low cost community networking solutions needed to facilitate market development.

2.1 Creation of Local Markets

The program explores the capacity and business models for all links in the supply chain from provisioning of passive infrastructure, data link and network deployment, operation and maintenance, to provisioning of end-user equipment, services and support for business development.

There is a narrowband VSAT link to the Internet. The focus regarding services provided is however on local communication needs exploiting the capacity within the broadband island.

The main focus was on four sectors: health, education, local government administration and business community. The two districts have a population about 466,609 while the whole region has a population of about 1,368,602 [3]. To develop this market, we have been running ICT awareness seminars and workshops; conducted baseline studies [9] and advertised ICT potential opportunities requesting local entrepreneurs to participate. The market is also supplemented by tourists visiting the Serengeti National Park.

To create ownership at the ground level, the project works hand in hand with the district council and local ISPs as partners. The sustainability ensured by sensitizing the users to budget for the ICT equipments, maintenance and bandwidth. Also, internet is being provided to individuals and private companies in the area to strengthen local ownership as well as share bandwidth costs.

The basic services for which the Serengeti network is designed include voice and video over IP, emails, web surfing, shared document repositories, web hosting and browsing, emails, data caching and backup services [1]. Also, this is a complete network with its own network services like DHCP and DNS.

2.2 Management architecture, Monitoring and Maintenance

To provide a reasonable availability of the network services and best performance, we facilitate remote monitoring of equipment and include as much redundancy as can be afforded.

For monitoring purposes we provide remote login to all network components and connect monitor servers at strategic locations in the network. Tools we use for monitoring include the nmap, ntop, nagios, mrtg and environment statistics from key network components [1].

2.3 Use of Low cost equipments

Both networks are using low-cost Ethernet switches with long range Optical Gigabit Ethernet transceivers to provide backbone transmission and fibre access. They also use wireless operating in license-free spectrum (802.11b/g) as access networks.

Routers and servers in the network are all based on standard PC hardware and Free Open Source software. Base station towers and boxes to house the active equipments in the field are manufactured locally.

3. DESIGN CHALENGES

In this section we discuss some of the main challenges in the Serengeti pilot network design as well selection of the equipments was supposed to take into consideration. It should be noted that we had a fixed budget to work with.

3.1 Topology issues

3.1.1 The backbone network

Since physical infrastructure, such as roads, power lines, water and sanitation are designed to serve more or less the same locations, fibre cables deployed along other infrastructure passes, in general, the right locations. The combination of infrastructures for communication and power distribution is a good match also for other reasons. They complement each other well since ICT usage requires power and contributes to the development of the electrical power market at the same time.

The best locations for local communication hubs in the backbone network, from the ICT4RD program point of view, are locations close to district council offices, schools and health centres. If wired access is used, right of way issues need to be considered, while of wireless access is used, the preference is a location where it is possible to get line of sight to all locations in the local access network.

The use of already installed infrastructure limits the topology of the network as not all requirements were considered in the installation process. The challenge in our case is that the locations where the fibre can be accessed are not always the best locations for the establishment of local communication hubs and not always at locations where it is also possible to access power.

3.1.2 Fibre handling

Optical fibre requires careful handling, both mechanically and optically. The splicing requires a reasonably clean environment, professional equipment and materials, and precise manipulation.

We have identified shortage of local human resources with these skills as a bottleneck and initiated the planning of education and training programs to deal with it.

The only node in the Serengeti network that is reasonably well protected is the Bunda endpoint located indoors at the TANESCO substation. All other fibre splices and network nodes are located outdoors in rural areas posing challenges to splicing and housing of both passive and active equipment, protecting them from rain, dust, insects and vandalism.

3.1.3 Access to power
Lack of stable power supply makes it necessary to include power backup systems at all network nodes with active equipment. We used batteries and an inverter to provide the backup power supply, solar could have been another alternative. More on this will be discussed in section 4.3.

3.1.4 Local access networks
Due to the locations, distances and the geographical topology, the local access networks in Bunda, Mugumu and Nata are all using wireless links. In Nata, it would be manageable to pull optical fibre from the power pole to the primary health centre to establish an indoor rather than an outdoor hub, but this has been left to a next phase.

Anyway, when planning the wireless access network, it was not possible to get line of sight to all locations to be connected from the location of the backbone hub, not even if a mast was placed there. It turned out that the best location to put a mast in Bunda was close to the primary health centre at Manyamanyama, located on a hill, while in Mugumu, it was behind the designated district hospital, also located on a hill. The WLAN equipment in Bunda and Mugumu are working in managed mode and the base stations there are thus working as wireless link relay stations, not directly connected to any of the primary network nodes on these locations. In Nata, however, the base station is directly connected to the backbone Ethernet switch and placed on top of the communication pole next to the power pole with the transformer.

4. IMPLEMENTATION CHALLENGES
The deployment of the Serengeti network is divided into four sections: site selection and building of communication stations, building the backbone network, providing backup power supply and the building access networks.

4.1 Communication Stations
The stations were chosen to be central points of access networks in Bunda and Serengeti towns, that is to say, it is at these stations where two towers were erected to be used for broadcasting radio signal to end-users. The following issues were considered and included in the choice, design and construction of stations.

4.1.1 Site locations
Bunda town (in Bunda district) and Mugumu town (in Serengeti district) were two areas of interests because are district capitals where majority of targeted users reside. A site location was found at Manyamanyama hill within the Health Center Compound in Bunda town. In Mugumu town a good location was found near the district hospital.

Figure 1: Access Point at Mugumu Communication Station.

4.1.2 Towers
100 feet tripod steel bar structure composed of ten sections, 10feet each was built to carry radio equipment and antennas. The head section has a triangular plate as its top where a metal bar is attached at the centre to hold a lightning rod as seen in figure 1.

4.1.3 Equipment room
Each station has an equipment room. It is a 2.5 meters square room with two windows aligned towards wind direction in order to maximize air circulation inside the building. The windows are covered with wooden levers on the outside and wire gauze on the inside to keep the insects out. An indoor metal cabinet is mounted on a wall facing the entrance in each room. Inside this cabinet is where all power adapters and other equipment are placed.

4.1.4 Earthing
Bunda and Serengeti districts receive much lightning during rain seasons. It was therefore necessary to ensure proper grounding of the tower and equipment room of each station in order to protect equipment from damage. Three holes were dug; three to five earth rods were connected in parallel, buried in each hole. The rods in holes were connected together to form a common ground. A lightning rod was attached at a tower top. A thick copper cable with one end connected to the top rod, was run to the tail section of the tower and connected at a common ground. The room's ground cable was connected to the same common ground as shown in figure 2 which shows the complete diagram.

4.2 Backbone Network

4.2.1 Physical and link layer
The fibre terminates at Bunda Tanesco Substation in Bunda town, Nata Distribution point, halfway from Bunda and Mugumu Distribution point in Mugumu town. From the termination points, the network is extended using WiFi to the communications stations. The fibre in use is a Single Mode fibre [4] with a total length of about 130km, beginning at Bunda, via Nata to Mugumu.

This fibre is lit by three daisy-chained Ethernet switches with optical interfaces at Bunda, Nata and Mugumu.

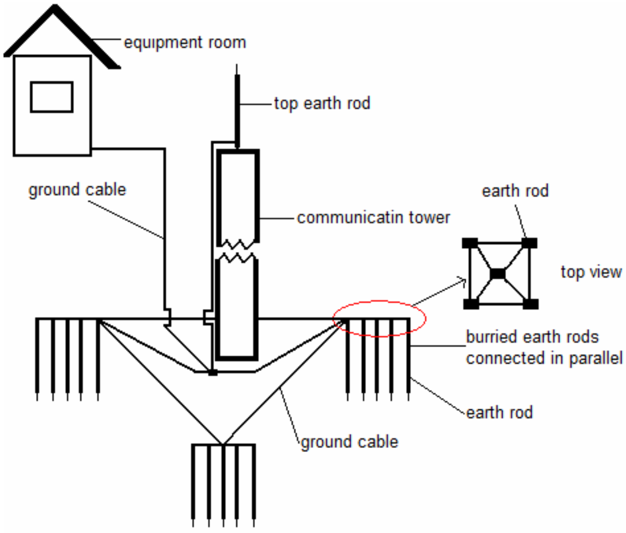


Figure 2. Ground cable connections.

The 802.11b wireless point-to-point link is composed of two Aeronaut 350A AP-radios [7] which have been configured to operate in the Wireless Distribution System (WDS) mode which allow APs to communicate to each other, in addition to communicating with client radios. The complete network diagram is depicted in figure 3.

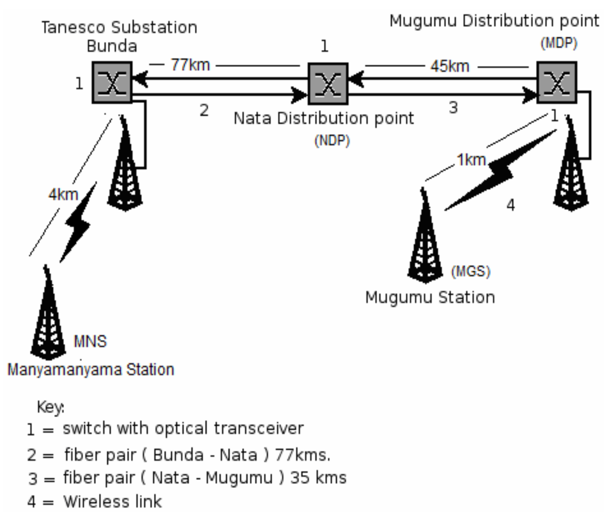


Figure 3. Backbone layout.

4.2.1.1 Ethernet Switches (With optical interfaces)

Three Cisco Catalyst 2950G-12EI switches with optical Cisco 1000BASE-ZX GBIC transceivers, located at Mugumu, Bunda and Nata light up a pair of fibre as shown in figure 4. Each switch has 12 10/100Mbps Ethernet ports and 2 GBIC module slots [5].

4.2.2 Outdoor Cabinets, Wooden boxes and Poles

There are a total of four outdoor enclosures, two are at Mugumu Distribution Point (MDP) and two are at Nata Distribution Point (NDP). Each metal cabinet houses an ODF and Cisco switch. Each wooden box houses a Tanesco LUKU meter, a Main switch, a Circuit breaker, two 50AH batteries, a Charger/Inverter, DC injector and electrical extension.

Figure 4. ODFs and switch at Nata Distribution Point

4.2.2.1 Outdoor Cabinet

It is a metal box designed and manufactured locally for outdoor installations. A design goal was to allow for good air circulation but block in-flow of water and dust. To achieve this, two side air openings and two sets of bottom air holes were made. Each opening has a blow-out AC fan attached in the interior and top-sealed cover on the exterior. Each cabinet has three holes at the bottom from which three 1ft metal pipes have been welded. These pipes save as inlet and outlets for fibre, power and STP cables.

4.2.2.2 Wooden Boxes

The solution involved the use of interlocking wood joints to make walls. Oil paint was applied on both inside and outside of the boxes to provide water tight seal. Two set of holes were drilled at the bottom to provide air-flow into and out of each box. These holes were covered with wire gauze to act as insect filters. The boxes top were roofed with pieces of iron sheets to prevent rain drops from directly hitting the top surface. Figure 5 shows outdoor enclosure mounted on the wooden pole. At the bottom of each box are an inlet and an outlet holes which have been fixed with cable grand.

Figure 5. Outdoor enclosures at Nata distribution point (wooden on the left)

4.2.3 Wireless point-to-point links

This is an 802.11b link formed by two Aeronaut 350 APs for the purpose of extending the backbone network to the communication stations. The AP is attached on a galvanized pipe at the upper part of the pole. An STP cable runs from a DC injector in the wooden box to the AP input port. The AP runs on Power over Ethernet (POE). The AP at MDP is shown in Figure 6.

Figure 6. AP and panel antenna at Mugumu Distribution Point

4.3 Backup power supply

Apart from the electricity from the utility company, there was a need for backup power supply at the termination points.

Backup solution involved using an Inverter/Charger and a set of deep cycle batteries. The Inverter/Charger charges batteries when general power is available; otherwise it inverts DC from the batteries to AC which powers the equipment.

4.3.1 Power requirements

For each location, a list of all equipment plugged into AC power mains was made. The listed power ratings were either provided by equipment manufacturers in the standard specification or calculated from input voltage (V) and current (A). A 10% of total power requirement was added to provide sufficient.

4.3.2 Batteries and Inverter/Charger

The batteries used are Exide maxxima 900 maintenance free deep cycle batteries with 50AH each. Inverter/Chargers are Triplite 600W. Figure 8 shows two batteries and Inverter/Charger placed in a wooden box.

Figure 8. Backup power system

The only active equipments in the termination points are an Ethernet Switch (30Watts) and a radio bridge/AP (25Watts). It was found that two batteries were sufficient to provide power for up to 12hrs.

4.4 Access Network

There are three wireless spots on the network that users can connect. These spots are formed by three Aeronaut 350 wireless APs located at MDP, MGS and NDP as shown in figure 9.

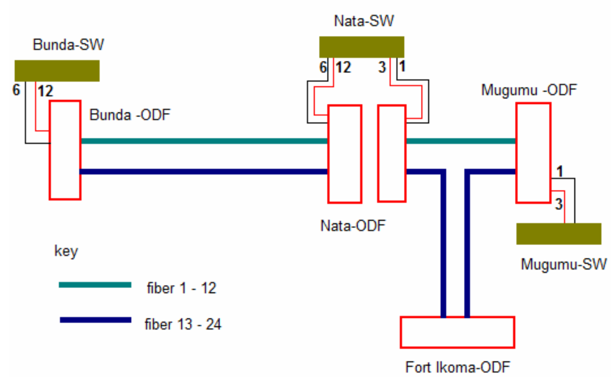


Figure 9.Fibre layout.

4.4.1 Access Point (AP)

4.4.1.1 Access Point at NDP

This installation contains an Aeronaut 350 and a 19dBi flat panel antenna. The two are connected by two 3ft LMR400 cables which are linked by a gas tube lightning arrestor (see Figure 10) and are mounted to a galvanized pipe at the top of wooden pole. The pipe and arrestor are earthed to a common point on the ground. The point contains 3 lightning rods buried into soil in a hole to provide earthing. This earthing is also shared by all electrical equipment placed in the wooden box.

Strong earthing was necessary to overcome the high lightning experience in Tanzania.

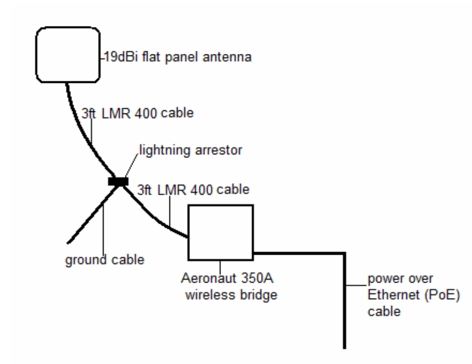
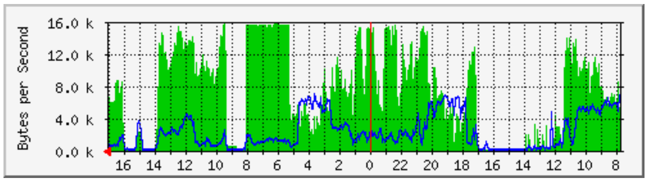


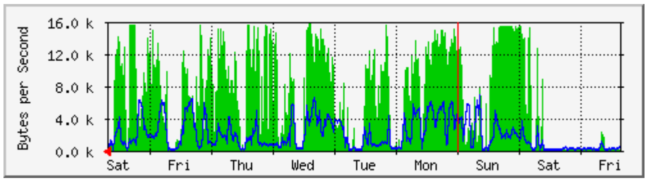
Figure 10. Access Point connections

5. NETWORK EVALUATION

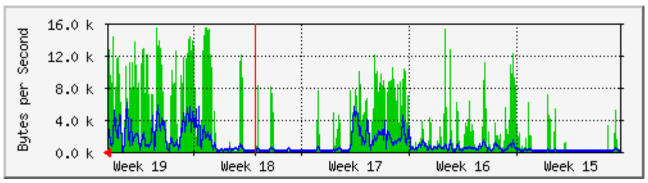
As the network has just put into production, we are currently monitoring the internet usage of the only available narrowband VSAT connection of 64kbps uplink and 128kbps downlink. The monitoring is done using MRTG [14] software. Figure 11 (a, b and c) indicates the daily, weekly and monthly graphs as seen on the 10th May 2008.



a. Usage on Saturday, 10th May 2008



b. Usage on the 19th week, 2008



c. Usage for April and May 2008.

Figure 11. MRTG Graphs for the link to the outside world

6. CONCLUSION

In this paper we have presented the Serengeti Broadband; a network deployed in the rural area in Tanzania. We have shown that it is feasible to build low cost networks in the rural areas of developing countries.

The goal is thus to provide all users with access to communication services at a capacity that is not a bottleneck. The superior infrastructure from a capacity point of view is no doubt optical fibre. There is little legacy copper network in Africa in general and none in the regions discussed in this paper. However, there is currently a momentum in the deployment of fiber, mainly in connection with other infrastructure projects, such as the extension of the power grid, in the rural electrification programme, along pipelines, railroads and roads among others.

Our contribution is in the use of local knowledge and manpower, low cost equipments and other existing infrastructures to provide high speed connectivity in rural areas fostering open access.

Future work involves better documentation, also implementation and enforcement of acceptable use policy. Further, we will perform network dimensioning to cater for expansion as the demand and usage is likely to grow as awareness increases.

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