Inclusive Ubiquitous Access - A Status Report

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Abstract. The development towards ubiquitous network access requires innovative solutions to get remote areas included, especially rural areas of developing regions. We report on recent progress in the Serengeti Broadband Network, one of the first pilots established in the Tanzania ICT for Rural Development programme with the mission to design and validate a method to establish sustainable broadband markets in under-served areas. The challenges include ownership and leadership, sustainable business models, robustness of network components and poor or non-existent supply chains, including power supply.

1 Introduction

We report on experiences and results from the Serengeti Broadband Network (SBN) established in the Tanzania ICT for Rural Development (ICT4RD) programme [1,2]. The mission of the programme is to design and validate a reproducible and scalable method to establish sustainable broadband markets in areas with demand but no supply of services. The method involves local communities in demand-driven first mile social business initiatives in order to speed up the deployment of commercial last mile connectivity [3]. The method aims at reducing all sorts of risks by demonstrating feasibility and start building local supply-chains. While everybody is invited to use the network and contribute to the running costs, the strategy to facilitate infrastructure investments is to primarily target basic public services prioritized in regional, national and local strategies, such as healthcare, education and local administration, including environment monitoring, climate change adaption, support to local entrepreneurs, etc. These services are taken as the starting point for iterative pre-commercial procurements in which local government specifies needs and requirements and issues calls for tenders, including invitations to form time-limited public private partnerships regarding services that cannot yet be considered commercially available and need to be developed before a next procurement. Since local communities often lack the competence and experience necessary to initiate and drive this process, they need to team up with independent advisers that can also facilitate capacity building. The method tested in the ICT4RD program is to use

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local research and higher education institutions, such as universities or colleges, as such advisers, since they are clearly independent, can engage senior students that soon are available on the labor market and can easily themselves get support from more resourceful peers at a global level, e.g. via the recently formed Technology Transfer Alliance of universities facilitating involvement of their faculty members and students in development cooperation projects for academic credit. SBN is an example of a network designed and deployed by PhD and senior MSc students in cooperation with other stakeholders. Their work also includes deployment of services, evaluation of usage, etc. There are efforts to take the lessons from the ICT4RD project in Tanzania to extend it to neighbouring countries under the African Great Lakes Rural Broadband Infrastructure (AGLARBRI) proposal [4].

The challenges include, on the business side, ownership and leadership issues, sustainable business models, awareness of the benefits of ICT, especially regarding local communication needs vs Internet access, how to combine a top-down and a bottom-up approach and lack of confidence in the community caused by the "consultant knows everything" syndrome [5]. On the technical side, the main challenges are robustness of network components, poor or non-existent power supply [6,7] and lack of trained human resources and financial resources to organise efficient network and service maintenance. There is also a lack of experience from how to organize pre-commercial procurements and public private-partnerships among stakeholders [8].

Positive developments include District Commissioners in both districts who are interested and supportive of ICT issues, and an increasing availability of data communication services provided by mobile operators. There are still, however, needs for services that the mobile networks cannot provide, which motivate further development of demand-driven inclusive ubiquitous access approach.

2 Background

The SBN backbone uses an optical fibre cable deployed in the medium-voltage power line between the capitals of the Bunda and Serengeti districts in northern Tanzania and includes a node in the Nata village between the capitals. SBN implements an IP-network on top of 1 Gbps Ethernet links. Initially, SBN was implemented as a single switched Ethernet as a proof of concept regarding transmission and applications. To make the network more scalable from a traffic aspect and sustainable from a power supply aspect, the backbone switches are being replaced by low-power routers. Two switches have been replaced by 12VDC routers consuming considerably less power than average routers of comparable performance. These routers are based on open source software and commercial off-the-shelf hardware components, selected to provide ISP-grade quality and the highest possible number of packets routed per energy unit (J) at a power level (W) low enough to facilitate the use of renewable sources. The routers have an integrated power management system accepting power from any 12–24 V power source, controlling the charging of a backup battery as well as the operation of

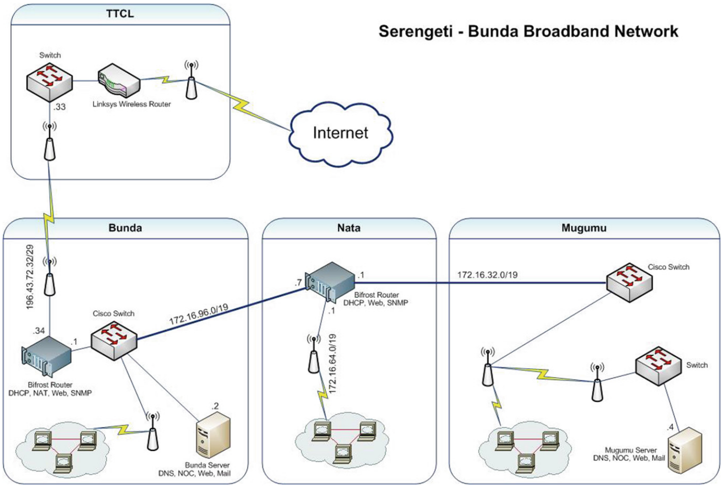


Fig. 1. Serengeti broadband network topology

the load to facilitate graceful shut-down when no power is available. The integration is part of our research aiming at extending the digital system architectures to include a power supply bus connected to a micro-grid with power sources, storage and loads in which energy can be routed on a demand and supply basis. Recently, the low-power routers were complemented with solar cells and a wireless sensor network measuring insolation, temperature and wind data. SBN end users are so far all connected via wireless links (WiFi). First mile fibre links are being discussed [2]. There are some 130 users connected, 100 in Bunda and 30 in Serengeti, including some local companies. The current network topology is shown in Fig. 1.

3 The System Improvements

Recently, new solar-powered routers with built-in power controller were introduced [6]. Three senior M.Sc. students were engaged in upgrading the SBN network and setting up Network Operating Centres (NOC) at DIT and KTH.

3.1 Deploying Low Power Hardware

The changes and additions introduced to the new low-power router include:

- *Modified cooling system:* Unlike the previous version, the new one has no active cooling components (fans). Cooling is done using heatsinks adherent to the top cover as shown in Fig. 2. This contributes to the reduction of power requirements and eliminate needs due to fan problems.
- *Improved charge controller:* The new router is capable of connecting two complementing power sources, e.g. solar panel and AC-adapter.

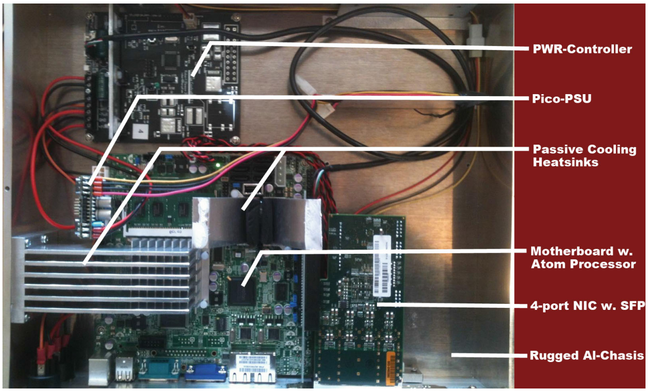


Fig. 2. Low-effect router, inside components

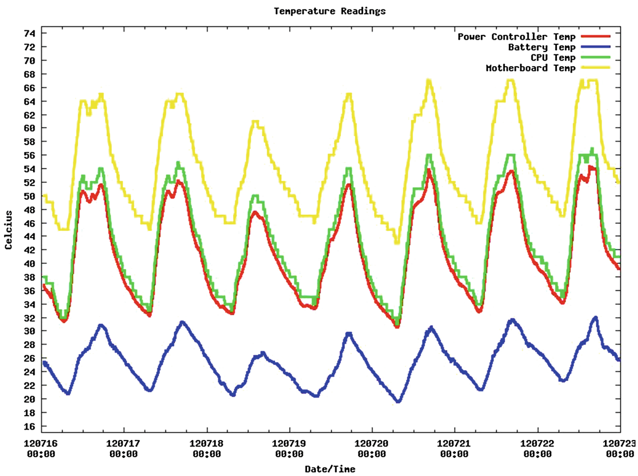


Fig. 3. Temperature reading, 7 days at Nata

– *Router Statistics:* Digital Optical Monitoring (DOM) statistics, including optical output and input power, laser, temperature and bias current can be collected from the optical transceivers in real-time. This facilitates troubleshooting optical communications and fibre status.

Given the harsh environmental conditions where the equipment is installed, it is important to monitor temperatures to prevent overheating that may damage and shorten the life of all electronic components as well as of back up batteries. Temperature is read from the charge controller, sensors are installed near the battery, in the router chassis, outdoors and from the motherboard and CPU using IPMI, see Fig. 3.

3.2 Alternative Power Sources

In Bunda, a maintenance free battery with a capacity of providing 12 v/100 Ah is used as a backup power source for the router. The battery is charged by the main power supply grid and serves as a backup power source during a blackout or power disruption. In Nata, two lead acid batteries are used as a backup power sources. A 65 W solar panel and an AC-adapter are used to charge these batteries.

3.3 Power Controller

The power controller works as a battery charge and discharge manager. It controls the charging of the battery from the input sources, AC-adapter and solar panel, and concurrently regulates the power supply to the router. When there is no input power, typically in case of failure of the power grid and solar power it not available, the battery will supply power to the router until the power sources are back or a Low Voltage Disconnect (LVD) limit is reached. In the latter case, the load (router) is disconnected in order to protect the battery from being fully discharged, which would shorten is lifetime. To facilitate parameter setting, monitoring, data collection and debugging, the power controller can be reached via a USB connection to the router.

Figure 4 shows the data collected via the power controller over a period of 24 h. The yellow line illustrates the battery current. It is positive when the battery is being charged and negative when the battery is being discharged. Between 18:45 to 21:10, there is no power from the AC-adapter or the solar panel and the router/load is then powered from the battery as is illustrated by the battery current going negative.

When the power sources are available, the power controller adjusts the battery voltage to “floating voltage” (approximately 13.5 V). The charging algorithm periodically boosts the voltage to approximately 14.5 V to prevent sulfurization. This is indicated with red line. When the boost threshold is reached, the charge voltage is decreased to the floating value, The battery current changes to small negative periodically. The green line shows the low disconnect voltage (12 V). To prolong the lifetime of the battery, the float and boost voltages are temperature compensated based on readings from a dedicated temperature sensor.

3.4 The Backoffice Network Operations Center

To support the local administrators with monitoring and troubleshooting, backoffice NOCs are set up at DIT and KTH. The web-based network management tools, Nagios and Cacti are used for monitoring. Wifi access points, routers, switches and server operation statuses are monitored by Nagios, which is installed in both the Bunda and Serengeti Servers. Nata and Bunda routers are also connected to Cacti that uses RRD tool for data logging. It allows for alerting and data graph access in case any routers become inaccessible. Data is being collected via the industry standard SNMP protocol as well as via scripts pulling data from the routers every 5 min. Collected data is being plotted in graphs that

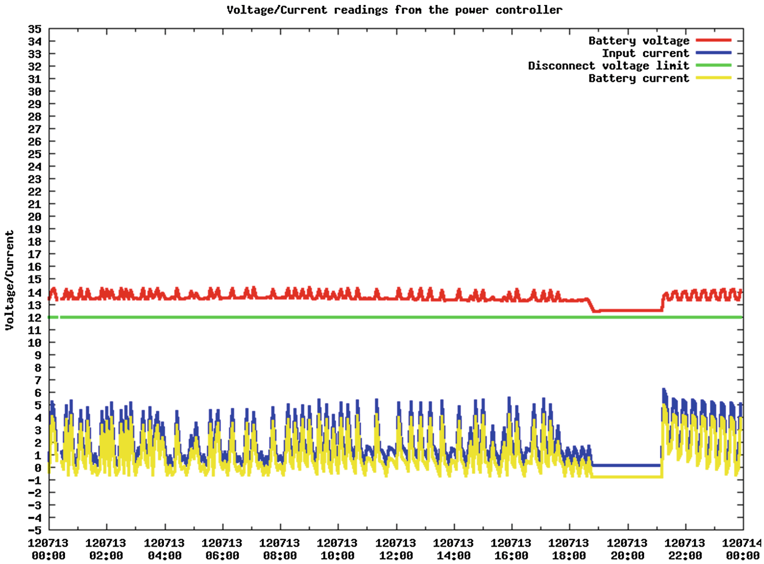


Fig. 4. 24 h data readings from the power controller (Color figure online)

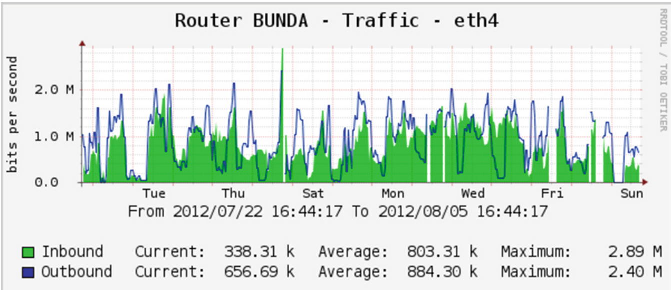


Fig. 5. Eth4 bandwidth utilization - Bunda router

are available in daily, weekly, hourly and yearly formats. Graphs being plotted include traffic information per each active interface, CPU usage, memory usage, temperature and charge controller stats. Figure 5 is an example illustrating the bandwidth utilization from the eth4 interface on the Bunda router.

3.5 Environment Monitoring via Wireless Sensor Networks

Some of the SBN routers have been instrumented for data collection via Wireless Sensor Networks (WSN) to gather site and environmental data. This is an experimental set-up to gain experiences and test equipment. In total five sensors are installed, three at DIT and two in the Bunda power station.

A WSN sink mote is connected to the router via USB collecting data from all the motes in the WSN network. Data fields are tagged and all data are

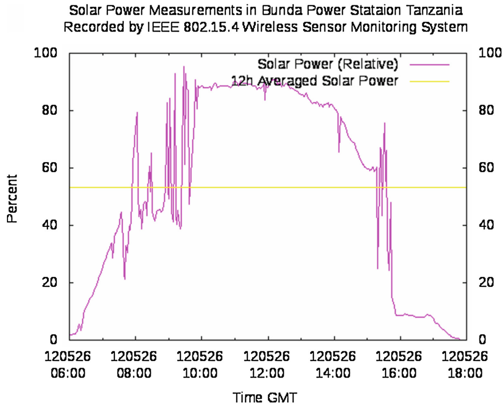


Fig. 6. Solar power measurement in bunda

sent and stored in ASCII format on the router. This WSN implements RIME [9], a broadcast scheme forming a simple auto-configured topology. The data is collected and directly made available via web access as raw data. In some cases plot and graphs are processed directly for instant analysis and monitoring. In Bunda, an insolation solar power meter is tested. This is a low budget solar power meter based on a small photo-voltaic (PV) solar panel loaded with a 50 Ohm resistor to report power via a WSN mote. The mote is reporting the voltage over the resistor. Another PV solar panel is powering and charging two NiMh AAA batteries to power the mote.

Our insolation measurements, Fig. 6 indicate a 12 h average about 50 % of the nominal solar panel power. A 1 kW panel would thus produce 0.5 kWh/h, 6 kWh/day, 2190 kWh/year. As a comparison, 800 kWh/year has been reported for Stockholm. With more data we will get the variation over time, which will affect the dimensions of the solar panel and battery back-up for a 24 h system.

At DIT, temperatures and relative humidity are collected from the Server room and selected offices. Sensors for measuring soil moisture is tested in collaboration with Swedish University of Agricultural Sciences (SLU).

3.6 The Applications

Both Bunda District (www.bunda.go.tz) and Serengeti District (www.serengeti.go.tz) websites are based on Content Management Systems (CMS) to provide information from district government, blogs and news feeds. Mail services were implemented in Bunda and Serengeti severs using open source applications (Postfix, Dovecot, Squirrel-Mail and Postfix Admin) to overcome the shortcoming of slow and unreliable Internet access. Sending and receiving emails within the local area network is more efficient.

Drug Management Application. A Drug Management Application (DMA) was designed and is about to be field tested. The objective is to minimize delays

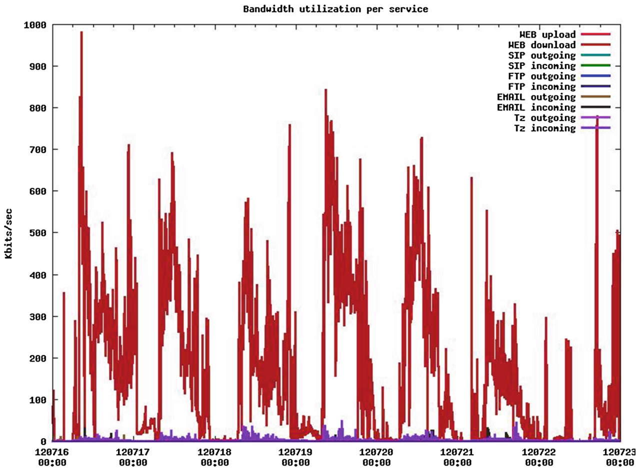
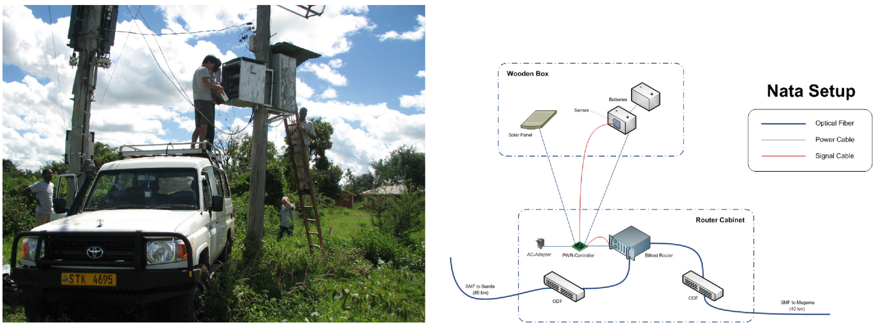


Fig. 7. Traffic utilization, 7 days in Bunda



(a) Replacing the Router (b) The Nata Set-up

Fig. 8. Installations in Nata (a) and (b)

in the logistic chain involving stock-taking, ordering and delivery of medical drugs to get a better balance between demand and supply of drugs. Orders can be sent to a drug distribution centre via a client-server application that runs on computers or android tablets or phones via HTTP or SMS. The application is expected to significantly improve current drug distribution process within local hospitals and healthcare centres. Tests on site regarding the technical aspects have been concluded successfully. Local authorities involved in the drug distribution chain are involved in the planning of a field test with end-users.

Traffic Statistics. Traffic statistics is being collected in both the Bunda and Nata routers via an iptables rule filtering out data in the following categories:

Tanzania: traffic destined to/from IPs allocated to Tanzania; Web: traffic to/from ports 80, 8080, 443; SIP: traffic to/from ports 5060–5070; FTP: traffic to/from ports 20, 21; and Email: traffic to/from ports 25, 110, 143, 587, 993, 995

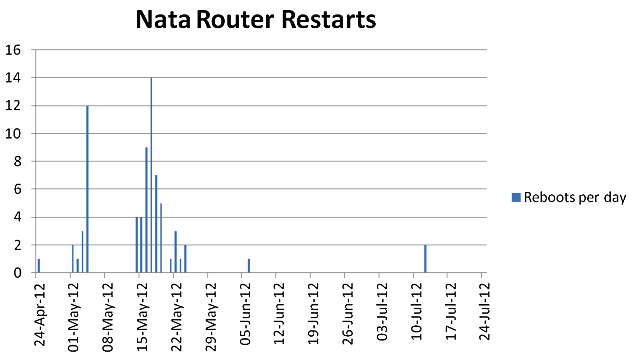


Fig. 9. Number of restarts per day

As seen in Fig. 7, the major part of the bandwidth is used by web applications. Note that the Bunda router is the Ingress and Egress point for Both Nata and Mugumu distribution points.

In order to reduce the bandwidth consumption, Squid is implemented as a proxy server in Bunda, so that webpage content is cached in the server and useless information such as advertisement and access to bad sites are blocked. Also, the proxy server facilitates collection of more traffic for further analysis.

4 Discussion

The current phase of the ICT4RD efforts has brought significant improvements in the availability, reliability and accessibility of SBN and the end-user services. Technically, the main improvements include more efficient monitoring and management due to the data collection and the support of the back-office NOCs. Stable power supply/backup is another major improvement. The combined performance of the deployed low power hardware, alternative power source and power controller is being evaluated based on the number of restarts happened per day before and after the new set up has been put in place, Fig. 8.

Figure 9 shows the number of restarts that have occurred on the router at the Nata station in the past three months. The router had restarted more frequently, even reaching up to fourteen times per day, in May, before the new set up was put in place. The number of restarts has significantly reduced in the next months, as a result of improved power management.

The network up-time has increased leading to a more reliable and dependable infrastructure. Note that, though most of the restarts was due to power disruption, some of the restarts are accounted for maintenance.

5 Conclusion and Future Plans

Still there are many challenges, both technical and non-technical in maintaining the network. The challenges range from decentralized management, awareness, hardware failures to power supply issues.

The decentralized management sometimes makes it difficult to have a common vision especially since the expenses in Bunda are not the same as in Mugumu. There are many connected users in Bunda than in Serengeti, on the other hand, there are more running expenses in Serengeti than in Bunda. Bunda don't pay for electricity as their NOC is hosted within the power utility company while Serengeti must pay for two nodes: Nata and Mugumu.

Device failure is another crucial issue as replacements are not easily available. There is no store/supplier within or nearby towns. It is necessary to have own stock to avoid long delays when there is a device breakdown.

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References

1. Information and Communication Technology for Rural Development (ICT4RD) Tanzania. http://www.ict4rd.ne.tz/
2. Nungu, A.: Towards sustainable broadband communication in under-served areas: a case study from Tanzania. Ph.D. Thesis. KTH, Stockholm (2011)
3. Pehrson, B., et al.: A First Mile Initiative, presented at UN Broadband Commission Working Group on Broadband and Science, Paris, France (2011)
4. Kahiigi, P., Kariuki, E., Kyalo, V., Masinde, M., Ngarambe, D., Nungu, A., Sansa-Otim, J., Pehrson, B.: African great lakes rural broadband research infrastructure. In: IST-Africa Conference (2012)
5. Nungu, A., Brown, T., Pehrson, B.: Challenges in sustaining municipal broadband networks in the developing world. In: Yonazi, J.J., Sedoyeka, E., Ariwa, E., El-Qawasmeh, E. (eds.) ICeND 2011. CCIS, vol. 171, pp. 26–40. Springer, Heidelberg (2011)
6. Nungu, A., Olsson R., Pehrson, B.: On powering communication networks in developing regions. In: Proceedings of the 16th IEEE Symposium on Computers and Communications (IEEE ISCC), Kerkyra (Corfu), Greece (2011)
7. Nungu, A., Olsson, R., Pehrson, B.: On the design of inclusive ubiquitous access. In: Proceedings of the Third International Conference on Ubiquitous and Future Networks (IEEE ICUFN), Dalian, China (2011). Received excellent paper award, extended version to be published in journal of wireless personal communication (2012)
8. Ngowi, H.P.: Public-Private-Partnership (PPP) in the management of municipalities in Tanzania issues and lessons of experience. Afr. J. Public Adm. Manag. **XVII**, 1–18 (2006)
9. Dunkels, A: Rime - a lightweight layered communication stack for sensor networks. In: Proceedings of the European Conference on Wireless Sensor Networks (EWSN), Poster/Demo session, Delft, The Netherlands (2007)

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