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Abstract: The African Great Lakes Rural Broadband Research Infrastructure (AGLARBRI) addresses the establishment of sustainable broadband markets in areas where there is demand but no supply of broadband services. The scientific objective is to validate the reproducibility, scalability and extensibility of earlier successful results from the Tanzania ICT for Rural Development program. The development objective is to accelerate the deployment of commercial last mile links by stimulating community based first mile initiatives. Under-served local communities in Kenya, Uganda, Rwanda, Burundi and eastern DRC are being targeted and supported by local research and higher education institutions to support capacity building. Innovative and affordable technical solutions based on off-the shelf hardware and open source software are being packaged for industrial distribution. The application focus is on inclusive ubiquitous access, and basic public services such as Healthcare, education and local administration. The project is well aligned with the new targets from the UN Broadband Commission, which clearly justify the mainstreaming of the results from Tanzania to the other neighbouring countries.

Keywords: ICT4D, Inclusive Ubiquitous Access, eInfrastructures, eInclusion, eAccessibility, eHealth, Health Information Systems

1. Introduction

The UN Broadband Commission has recently formulated four challenging targets for broadband policy, affordability and uptake to be reached by 2015 [6]. The African Great Lakes Rural Broadband Research Infrastructure (AGLARBRI) project, based on the results from the Tanzania ICT for Rural Development program [1], addresses several of these challenges. The results from Tanzania are discussed in a recent Ph.D.-thesis by one of the co-authors [2] laying out a strategy for establishment of sustainable broadband markets in areas where there is a demand for broadband services but no supply. The Broadband Commission and national targets justify the mainstreaming of these results to the neighbouring countries.

A basic assumption is that commercial providers will establish last mile links to under-served communities sooner rather than later if the communities themselves engage in social businesses providing first mile connections demonstrating feasibility and mitigating risks. Another basic assumption is that first mile initiatives raise interesting research and

development issues that motivate highly competent research and higher education institutions to assist [3] while at the same time developing new learning and job opportunities for their students.

The strategy laid out in [2] is conceptually simple: Attract investments by addressing basic public sector services, such as healthcare, education and local administration. Then turn every stone to find paying customers to cover operating costs. The challenge is in all aspects of the implementation of this simple strategy.

The ownership and leadership, the technical solutions, the business models, the cost-benefit analyses, the reorganisation of user work processes to take advantage of the services, education and training, etc. All these challenges are processes in themselves.

The ownership and leadership often starts with one or a few entrepreneurs seeing opportunities. In early phases, the first duty of such entrepreneurs is to stimulate the community, the trusted local government, to take ownership with the motivation to improve cost-efficiency in the provisioning of main-stream public services. Once the community is in the driver seat as the main customer, it has to develop a skill as pre-commercial procurer of development involving all entrepreneurs that can contribute in fair competition and with time limited mandates. This process will consist of a series of iterative procurements with time-limited private-public partnership contracts that eventually will develop a market with supporting supply chains. It may, however, take a decade or two, and will require transparent and audited iterative pre-commercial procurements to stay on track.

2. Objectives

The scientific objectives of the AGLARBRI project include validation of the reproducibility, scalability and extensibility of the basic strategies and methods tested in Tanzania. The geographical area in focus includes all EAC states and Eastern DRC in a ring around Lake Victoria and with links from Kigali to Bujumbura and Goma. The pilots in Tanzania include a network between the capitals of the Bunda and Serengeti districts in the northern Mara region. In Rwanda, two districts in the Eastern region, Ngoma and Kirehe are being considered. In Uganda, the three rural districts Isingiro, Mityana, and Iganga are being considered for participation in the AGLARBRI project.

The primary application focus is on healthcare and rational drug management, except in Burundi where secondary schools is a priority. The extensibility will be tested by broadening the ICT4D content to other priorities in the regional and national strategic development plans beyond the very basic public health, education and local administration services.

One example of such a broadening is to include climate change issues important to remote communities, including contingency strategies based on enhanced monitoring as well as mitigation strategies reducing emission of greenhouse gases. Our contributions in that area involves power-lean communication system designs with integrated power management, the use of renewable energy sources to power them and the use of physical as an alternative to chemical energy storage technologies based on batteries with ultra-capacitor cells rather than lead-acid cells.

3. Methodology

The AGLARBRI project started out using the same strategy as the one developed in the Tanzania ICT4RD program. The project is still only starting up and we expect the methods and tools to develop. The approach to implement the strategy includes:

- Identification and invitation of local communities (LCs) to participate in AGLARBRI and coach them in the formulation of their development plan
- Supporting the LCs in the establishment of their local area network
- Supporting the LCs to interconnect to each other and to their national networks

4. Technology Description

The technical solutions used in the Tanzania program are based on unlicensed radio spectrum (wifi) in the first mile networks and a passive dark optical fiber pair in publicly owned fibre cables for the access network. The active network components are all based on open source software and standard off-the shelf hardware components, including Linux routers, servers for network and end-user services, as well as Voice over IP and Video Conferencing clients at the end-user premises. The router design includes integrated power management supporting the use of alternative power sources and local power storage to sustain operations even with power outages where there is a power grid. The ultra-capacitor battery is still being tested in the laboratory environment.

Development is in progress regarding power-lean wireless sensor and actuator nodes for monitoring the quality of drinking water and other environment data. This development involves validating the ports of wireless senor network software platforms, such as TinyOS and Contiki, to the latest generation of Microcontroller Units, such as Atmega128RF , and interfacing sensors for monitoring of voltage, current, temperature and climate parameters such as temperature, humidity, pressure and light. A special power-lean gateway is being developed with all sorts of upstreams, including wired ethernet over copper and fiber, wifi, GSM, IEE802.15.4 and HF.

Some of the health related services that will be provided (in some/all the participating countries) include:

- A Drug Management Application (DMA) runs on tablet or regular PCs and helps health facilities to keep track of drug inventory and to order new drugs.
- High Definition Video Conferencing (HDVC) supports high definition video conferencing between multiple parties therefore suitable for medical purposes.
- Residential gateway enables patients to connect from their homes to the medical network which health professionals can access in order to provide remote care.
- The Medical Records System provides a 360-degree patient records solution.
- The Sensor Gateway an Android-client interfaces with pulsemeters and pushes data to a central server which then distributes it to targeted health professionals.

5. Developments

5.1 – Tanzania

Key actors in Tanzania include: 1)Universal Communication Access Fund (UCAF), tasked to speed up implementation of universal access policies through expansion and coverage of ICT services to rural and less profitable communities; 2)Tanzania Communication Regulatory Authority (TCRA), the leading agency of the government with the obligation of promoting efficient communication services and increase access to ICTs, and promoting efficient, reliable and affordable communications infrastructure and applications; 3) the Tanzania Commission for Science and Technology (COSTECH) responsible for coordinating research in the country; and 4) the Ministry of Science, Communication and Technology which is currently planning to facilitate creation of 3,000 telecentres in the country by 2015. A number of ICT initiatives have been taking place in the country including the National ICT Broadband Backbone (NICTBB) which is expected to connect all district capitals, as well as provide connectivity to almost all neighbour countries as shown in Figure 1.

NICTBB has 7 objectives: i) To increase the usage of ICT for equitable and sustainable socio-economic and cultural development of Tanzania; ii) To establish a Point of Presence in all country's administrative districts; iii) To facilitate the implementation of e-government, e-health, e-commerce, and e-education initiatives; iv) To make ICT related services particularly Internet affordable and readily available to common Tanzanians; v) To

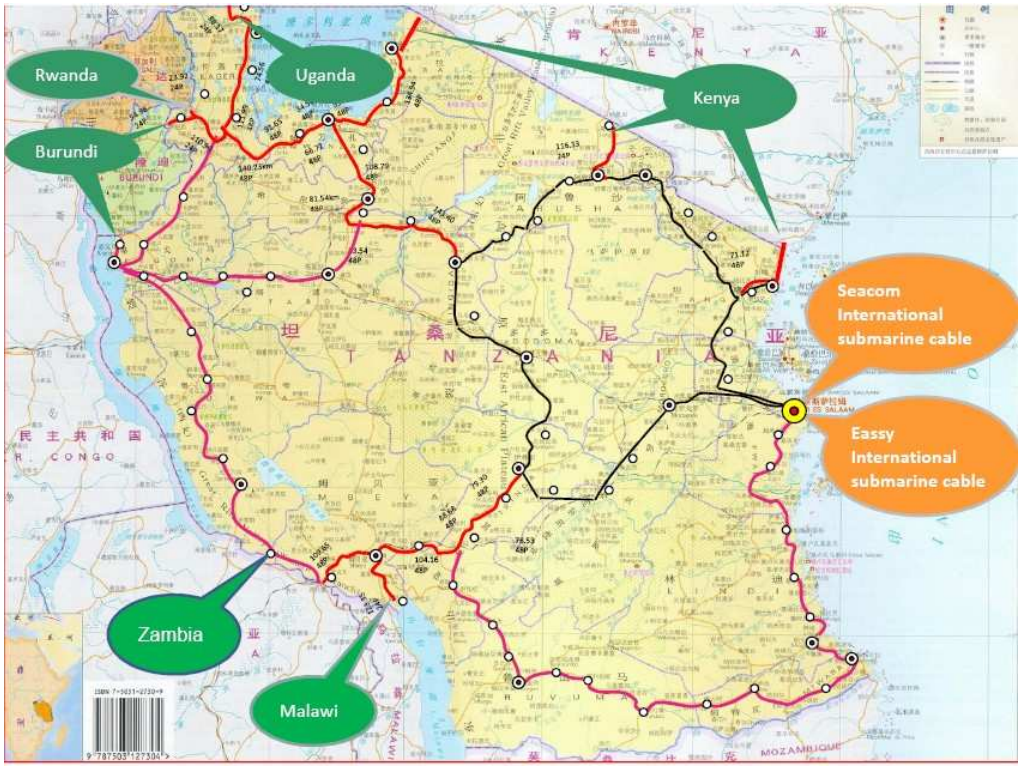

Fig 1: Tanzania National Backbone Map [4]

provide access to international submarine fibre optic cables via Dar es Salaam landing point to all landlocked neighbouring countries i.e. Uganda, Rwanda, Burundi, Malawi, Zambia and the Democratic Republic of Congo; vi) To create a favourable environment for cooperation and partnership in ICT among public and private sectors, civil society, and between all stakeholders at local, national, regional and international levels; vii) To provide equal access to the ICT backbone network to all licensed operators for the sake of creating an open and healthy competitive environment in delivery of ICT services.

Other government ICT initiatives through the ministry of Communication, Science and Technology (MCST) include the National ID Project, a network connecting Governmental Ministries, Departments and Agencies and Community Resource Centers.

5.2 – Rwanda

In line with the Integrated ICT-Led Socio-economic Development Plan for Rwanda (NICI) II which was concluded in 2010, that placed great focus on developing key ICT infrastructure, the Broadband Infrastructure in Rwanda has 3 major broadband infrastructure projects:

- The National Backbone (NBB) extends links to all major towns in Rwanda and provides onward connectivity to submarine cables through Uganda, Burundi, Tanzania and the Democratic Republic of Congo (Fig. 2). The NBB Optical Fiber Network has a total coverage of 2300 km connecting all districts headquarters; Schools and Universities (supporting Rwednet); Hospitals and health centers; Social Security fund offices; Rwanda Review Authority (RRA), Customs offices and Banks' branches, judiciary offices, and ORTPN sites; Border posts and immigration offices and police stations; and Border post connectivity for regional and international traffic
- Optical fiber Kigali Metropolitan Network (KMN), which interconnects to the NBB, and has coverage of 57 km around Kigali city, connecting 54 Government buildings and 63 agencies. It has a capacity of 10 Gbps (STM-64), with 1 Gbps network equipment for each government site.
- Wireless Broadband network (WiBro): Wireless Broadband network (WiBro) in Kigali area, provides superior broadband data, voice and video services. The network consists of optical fiber transmission, and wibro radio equipment. The project is divided into phases: Phase 1 covers the Kigali City, and Phase 2 covers other five provincial capital cities.

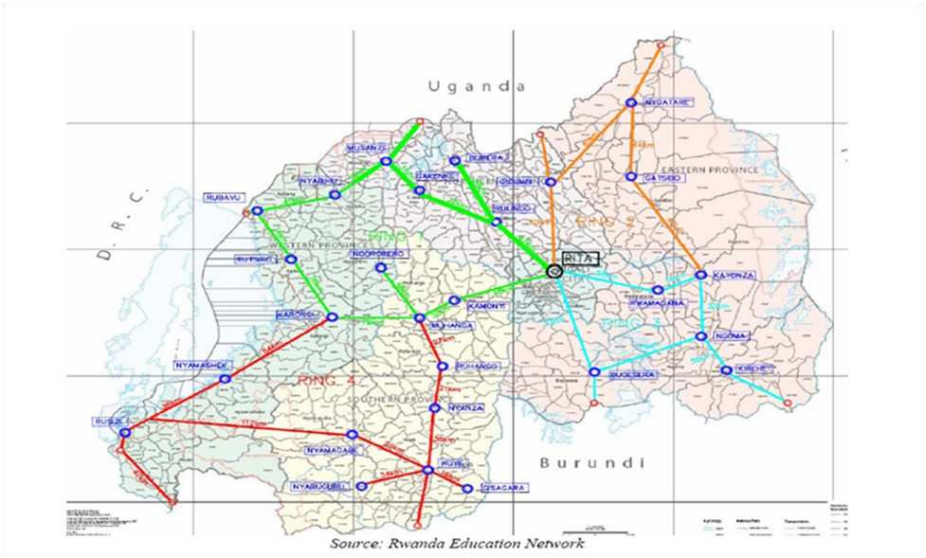

Fig 2: Rwanda's NBB Infrastructure

Infrastructure Challenges are being addressed by the efforts of the Rwanda Development Board the branch of IT (RDB-IT), and the telecommunication operators which include Rwandatel and MTN RwandaCell, and fiber networks and Several ISP providing WiMax Solutions now existing in Rwanda. All the broadband infrastructure services are now being privately operated by the Broadband System Corporation (BSC) Ltd., a licensed Internet Service Provider (ISP). The company is engaged in the business

of providing advanced Information Communication Technology services based on broadband connectivity.

Under the AGLARBRI project, two rural community sites in Rwanda have been identified. These are Munini hospital in Nyaruguru district (bordering Burundi), and the Kirehe district hospital, in Kirehe district (bordering Tanzania). Each district hospital is responsible for an average of 14 health centers. Both these sites are in the most rural parts of the country and face a communication challenge, currently information is received during scheduled visits to the health centers. The project is already working on plans to develop wireless networks to enable easy communications between the district hospitals and associated health centers.

5.3 – Uganda

In Uganda the key actors include the Uganda Communications Commission (UCC) and National IT Authority of Uganda (NITA-U) both of which are government institutions under the Ministry of ICT. UCC administers the Rural Communication Development Fund (RCDF) which was established in 2003 and is funded from 1% of telecom operators' licenses. It has implemented several projects including: 76 Internet points of presence (POP) at districts, 106 Internet cafes, 78 ICT training centers, 78 District web portals, 13 Multi Purpose Community Tele-centres (MCT), 708 School ICT laboratories, 174 Health ICT facilities, and 106 content development projects. The direct impact of these projects is: 100% data coverage for every district town of Uganda, teaching of Computer Studies as a subject in at least 50% of government secondary schools and basic ICT equipment in all district government hospitals.

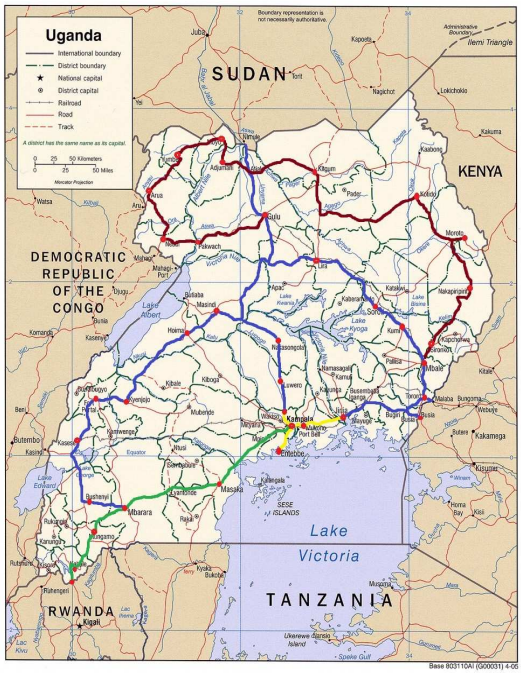

Fig 3: Map Showing Proposed Phasing of the NBI/EGI Project, , source: NITA-U.
KEY: Phase I (Yellow) Phase II (Blue) Phase III (Green) and Phase IV (Maroon)

NITA-U is implementing the National Data Transmission Backbone Infrastructure and e-Government Infrastructure (NBI/EGI) Project (illustrated in Fig 3), which aims at connecting all major towns within the country onto an Optical Fibre Network and linking all Ministries and Government Departments onto the e-Government Network. The NBI/EGI project Phase I and phase 2 were completed in June 2008 and August 2011 respectively, and involved the laying of Optical Fibre Cable of 168Kms and 1368.39kms respectively.

Phase 3 is currently under implementation. The expected benefits of the **NBI/EGI Project are:** (i) Cost reduction of doing business and public administration in government, improving communications between government agencies, and the delivery of E-Government services within government, to citizens and businesses; (ii) Affordable country-wide high bandwidth data connection; and (iii) A more accountable Govt. While all these projects increase broadband access in Uganda, the following persist as challenges: (i) Low usage of the existing infrastructure; (ii) Sourcing for low powered computers and other networking elements; (iii) Honesty of project implementers.

The AGLARBRI project will contribute towards addressing the above challenges. The participating rural districts in Uganda are yet to be agreed upon by all partners; however, Isingiro, Mayuge and Mityana have been identified as suitable candidates. The Wireless Networks and Systems Security (WNSS) Research group of Makerere University and the Research and Education Network of Uganda (RENU) are already partners in the project. Discussions are underway to ensure active participation of NITA-U, UCC, the Ministry of ICT, and the Uganda National Council of Science and Technology (UNCST).

5.4 – Kenya

The Kenya Ministry of Information and Communications (MoIC) in its mandate to develop National Information and Communication infrastructure and capacity has so far completed;

1. **International Connectivity via submarine fibre.** The government has achieved international connectivity through TEAMS, SEACOM and EASSy submarine cables. The LION2 cable is expected to be completed by 2012. This will in essence provide quality and reliable international connectivity to the country and the region at competitive costs.
2. **National Connectivity Backbone:** The 1st Phase of the National Optical Fibre Backbone Infrastructure (NOFBI) which covers the major towns across the country has been completed as illustrated in Fig 4 below. The government plans to expand the network to cover more towns as well as complete the network loops for redundancy routing in phase 2 of the project. This will also involve connecting strategic institutions including public, social and learning institutions.

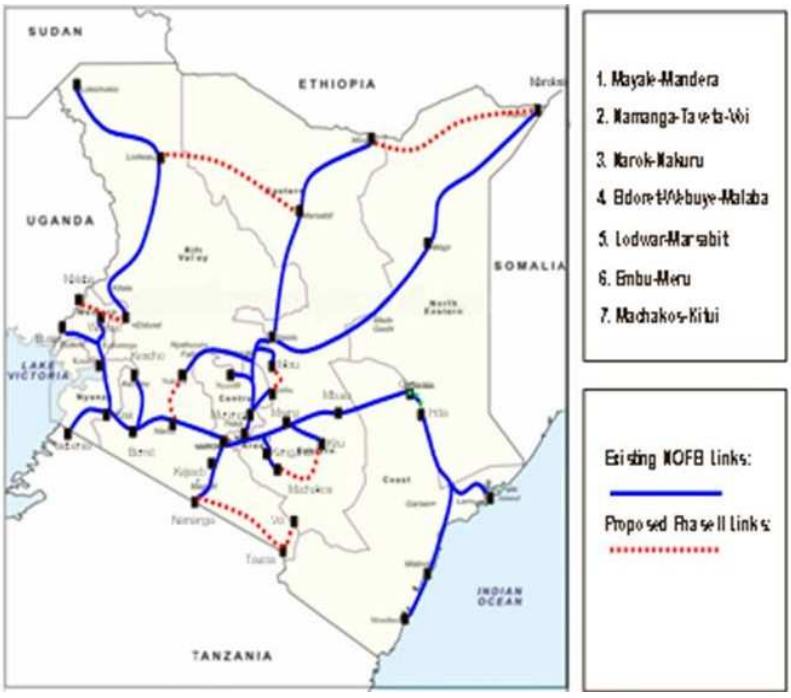

Fig. 4: Optic Fibre Backbone Infrastructure (NOFBI) Network

3. **Last Mile Connectivity:** The Government has invested in Government Common Core Network (GCCN) to connect all government buildings in Nairobi. Leveraging on NOFBI, connectivity will be extended across the country. This will enable the Government to roll out e-services countrywide. The private sector such as instance Kenya Data Network (KDN), TKL, Jamii Telkom, Access Kenya, Wananchi, Safaricom, Airtel, TKL and Yu has also contributed substantially in the provision of last mile connectivity. In addition Kenya Education Network (KENET) continues to expand across the country and currently serves over 60 tertiary institutions countrywide.

A major challenge is in the delivery of quality and affordable bandwith to institutions and individuals in the far rural areas. Use of the network for delivery of services to communities is paramount to the success and sustainability. AGLARBRI will contribute greatly to achieving both connectivity and application (with a bias to health sector) at the community level in rural areas. Discussions and collaboration between Kenya ICT Board, KENET and the University of Nairobi (School of Computing) are currently ongoing. The initial areas of focus are planned to be Western Kenya (around Lake Victoria) and in the Eastern part of the country. Initial identification and contact with the potential participating hospitals is ongoing.

6. Results

Cognizant that Community Broadband Networks (CBNs) stimulate rural broadband, this project validates a framework for establishment of sustainable broadband markets [5] in rural underserved areas. This CBN integrated approach as implemented in the Tanzania ICT for Rural Development program (illustrated in Figure 5 for the Serengeti Network) is being reproduced at several sites in the participating countries. This approach ensures that CBNs are sustainable by establishing local community good will (through the promotion of local ownership and local communication needs identification & services provisioning), CBN technical committee mentorship, ICT awareness raising and capacity building, methods that support the consolidation of the ICT supply chains, universal access business models and technical solutions to cater for the lack of infrastructure.

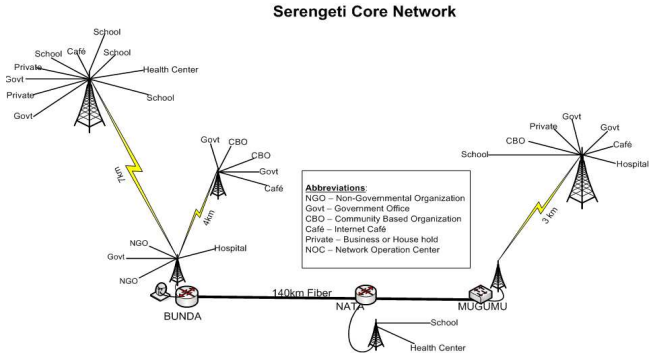

Fig 5: Serengeti Networks [5]

7. Business Benefits

The overall expected impact of the AGLARBRI project is to complement the UCAF initiatives in each country, at a regional level, empowering the local communities to participate in connecting their communities. This in turn will open up these locations to a wider community of researchers for socio-economic development. The direct benefits will be inclusive ubiquitous access, and improved quality of basic public services such as Healthcare, education and local administration.

8. Conclusions

Stakeholders including academia, R&E networks, and government agencies in the participating countries are collaborating to implement the AGLARBRI project. In each country the pilot rural communities have been identified. Since the AGLARBRI project contributes towards the national development plans of the participating countries, in some countries the active participation of the relevant government agencies has been secured while in others discussions are underway to secure this participation. Invitations to the local communities are currently being designed.

The further work in the implementation of the AGLARBRI project include: coaching the rural communities in the formulation of their development plan, supporting them in the establishment of their local area network as well as interconnecting them to each other and upstream to their national research and education networks.

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