Master's Thesis

Reproducing ICT4D Tanzania to a Rwandan District

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Abstract

Key words: healthcare, ICT4RD Tanzania, ICT4RD Rwanda, AGLARBRI, infrastructure and applications reproducibility

ICT based health care policies in developing countries must be targeted at the poorest most rural member of the population where there is demand but little or no supply of health care. This is achieved through ICT4RD program which mainly focus on provisioning of ICT access to rural areas. In this regard, ICT4RD Tanzania built a local broadband which pass through fifteen villages around Serengeti district to benefit health, government and education sectors. There have been a number of discussions between countries located alongside the African great lakes to build a sustainable rural community networks providing basic public services as a research infrastructure network. The main motivation is to facilitate first mile initiatives to explore and demonstrate methods and solutions that could eventually be used to commercial actors to build production networks in areas where there is demand but little or no supply. The discussion has passed all the way and become a project called AGLARBRI(African Great Lakes Broadband Research Infrastructure). At this critical time, it is of technical interests to see if rural regions around the African great lakes could benefit from previous similar projects like Tanzanian ICT4RD project.

This thesis addresses the aforementioned basic interest and uses a comparative case study tool to formulate and analyze the reproducibility of technical solutions produced by ICT4RD Tanzania program to a selected district in Rwanda. Intensive study on ICT4RD Tanzania technical solutions, on-site survey and radio mobile simulation analysis has been performed. Interview with health center employees, IT support personnel's, and stakeholders, online questionnaires, direct observation while performing site survey and online official resources are used as primary and secondary source of data.

The outcome of the thesis reveals that infrastructure design proposed by ICT4RD Tanzania program using fiber-wireless technology can also be used for a rural district in Rwanda in a similar fashion after considering local telecommunication regulations. It also proves that a great care needs to be taken while reproducing services between regions. Service reproducibility has also shown a failure to some extent. This is revealed by the use of Drug Management Application (DMA) and webmail applications. DMA application couldn't be reproduced because the two rural areas used for comparison have different work flow for drug management. Reproducibility of webmail application has also shown a filer due to the fact that webmail system is not current interest for Kirehe district healthcare system. The outcome of the thesis also proves that ICT4RD Tanzania proposed infrastructure design solutions can be scaled and extended for similar rural areas along the AGLARBRI ring. Furthermore, service demand and work flow analysis is crucial to reproduce services along the area.

Sammanfattning

Nyckelord: vård, ICT4RD Tanzania, ICT4RD Rwanda, AGLARBRI, infrastruktur och applikationer reproducerbarhet

ICT-baserad hälso-och sjukvård politiken i utvecklingsländerna måste riktas mot de fattigaste mest lantliga medlem av befolkningen där det finns efterfrågan, men liten eller ingen utbudet av hälso-och sjukvården. Detta arkiveras genom ICT4RD program som främst inriktas på tillhandahållande av ICT tillgång till landsbygden. I detta avseende byggde ICT4RD Tanzania en lokal bredband som passerar genom femton byar i närheten av Serengeti distriktet till att förbättra hälsan, myndigheter och utbildningssektorerna. Det har förekommit ett antal diskussioner mellan länder som ligger vid sidan av de afrikanska stora sjöarna att skapa en hållbar landsbygd med nätverk som ger viktigaste offentliga tjänster som en forskningsinfrastruktur nätverk. De viktigaste motiven är för att underlätta första milen initiativ att undersöka och demonstrera metoder och lösningar som kan så småningom skulle användas för att kommersiella aktörerna bygga upp produktions nätverket i områden där det finns efterfrågan, men liten eller någon leverans. Diskussionen har gått hela vägen och bli ett projekt som kallas AGLARBRI. På hans kritiska tiden är det av tekniska intresse att se om landsbygden runt de afrikanska stora sjöarna kan dra nytta av tidigare liknande projekt som Tanzanias ICT4RD projekt.

Denna avhandling behandlar tidigare nämnda grundläggande intresse och använder en jämförande fallstudie verktyg för att formulera och analysera reproducerbarhet av tekniska lösningar som produceras av ICT4RD Tanzania för en vald distrikt i Rwanda. Intensiva studier på ICT4RD Tanzania tekniska lösningar, plats undersökning och radio mobil simulering analys har utförts. Intervju med hälso center, IT-stöd Personalens och intressenter, online frågeformulär, direkt observation under utföra platsundersökning och online officiella resurser används som primär och sekundär datakälla.

Resultatet av thesis visar att konstruktionen av infrastruktur som föreslagits av ICT4RD Tanzania programmet med fiber-trådlös teknik kan också användas för en kommun i Rwanda på ett liknande sätt. Den visar också att en stor försiktighet måste tas samtidigt reproducerar tjänster mellan regionerna. Tjänsten reproducerbarhet har också visat ett misslyckande till viss del. Det visar med hjälp av DMA och webb post tillämpnngar . DMA tillämpning kunde inte reproduceras eftersom de två landsbygden används för Jämförelsen har olika arbetsflöde för läkemedel förvaltningen. Reproducerbarhet av webb post tillämpningar har också visat ett Filer på grund av att webbmail systemet inte är ett intresse för Kirehe distriktet hälso-och sjukvården. Avhandlingen visar också att ICT4RD Tanzania föreslagna infrastrukturen utformning lösningar kan skalas och förlängas liknande landsbygden längs AGLARBRI ringen. Dessutom är efterfrågan på tjänster och arbete flödesanalys är avgörande för att reproducera tjänster längs området.

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Glossary

AGLARBRI	African Great Lakes Rural Broadband Research Infrastructure
BSC	Broadband Systems Corporation
CSD	Communication System Design
DHCP	Dynamic Host Configuration Protocol
DMA	Drug Management Application
DRC	Democratic Republic of Congo
ICT4D	Information and Communication Technologies for Development
ISM	Industrial, Scientific and Medical radio bands
KI	Karolinska institute
KIST	Kigali Institute of Science and Technology
KTH	Royal Institute of Technology
LVM	Logical Volume Management
MTN	South-African based, multi-National telecom company
NICI	National Information and Communication Infrastructure strategy for Rwanda
NUR	National University of Rwanda
OLPC	One Laptop Per Child
RAID	Redundant Array of Independent Disks
RDB	Rwanda Development Board
REHCE	Regional e-Health Center of Excellence
RURA	Rwanda Utilities Regulatory Agency
SER	SIP Express Router
SPIDER	Swedish Program for ICT in Developing Regions
TSLAB	Telecommunication Systems Laboratory
TANESCO	Tanzanian Electric Supply Company

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1. Introduction

Rwanda is a small landlocked country located in the east-central part of Africa with surface area of 26338 Sq Km. It is bordering with Tanzania, Uganda, Burundi, and DRC with an approximate population size of 8.2million[1] according to the last censuses made by 2002. Even though Rwanda still remains in agrarian based economy with more than 60% of the population living under poverty line, it has made a significant progress since the 1994 genocide. The severe shortage of professionals hinders the development strategy of all sectors. To elevate these problems the government of Rwanda has set an ambitious national goal that the country joins middle-income economy countries by 2020. Regarding the healthcare unit the main objectives include reducing the infant rate from 107 to 50 per 1000 and maternal mortality rate from 1070 to 200 per 100,000. Malaria and other potential epidemic diseases shall also be controlled and HIV prevalence will have been reduced from 11.2% to 8%.[2] To achieve these goals and improve access and quality of healthcare at a reduced cost, healthcare policies must be targeted at the poorest most rural member of the population where there is demand but little or no supply of healthcare. This can be achieved through ICT4RD program which mainly focus on provisioning of ICT access to rural areas where 84.1% of the population resides[1].

ICT4RD Tanzania is one role model for ICT4RD program which provides broadband connectivity for fifteen villages along the power line between Bunda and Mugumu towns using wireless and fiber optic technologies. After accompanying a serious of discussions between countries located alongside the African great lakes region, they decided to build a local research broadband infrastructure through AGLARBRI project. The project mainly investigates the reproducibility, scalability, and extensibility of the positive results obtained in previous similar projects like Tanzania ICT for Rural Development program. It aims to build a sustainable rural community networks providing basic public services as a research infrastructure network by activating local communities in rural areas of the African great lakes region.

At this initial stage of AGLARBRI project, it is paramount to address infrastructure and service implementations to see if rural districts of the region could benefit from similar previous projects. Various technical solutions are proposed by ICT4RD Tanzania program which can be grouped into network connectivity, electric power usage, and healthcare services. The thesis validates the reproducibility of those technical solutions to a selected rural district in Rwanda and answers the basic question: “Is it possible to reproduce, scale, and extend technical solutions obtained by ICT4RD Tanzania to build a local broadband infrastructure to a Rwandan district and the AGLARBRI region as a whole?” The thesis mainly takes ICT4RD Tanzania project as a role model and validates the reproducibility of proposed technical solutions through a case study.

2. Background

2.1. Previous work study on ICT4D

Information and Communication Technology

ICT plays an important role in the area of politics, economic and social affairs. ICT is also believed to affect the way people do business, the way they perform their task, and communicate each other. According to the mission statement made by the National Information Technology Policy, information and communication technology can be used for education, wealth and job creation, poverty reduction and global competitiveness. To understand how information and communication technology can be used for various sectors and its contribution for global development, it is vital to first define the word itself.

A number of researchers have defined Information and communication technology in different ways. John Giles[3] uses the acronym ICT for two stands; "Information and communication technology" and "information, communication and technology". According to his explanation, the first acronym option takes information or communication with technology. It means that information and communication can't exist without technology. On the other hand his second option for ICT allows the existence of each of the acronym by its own. Furthermore he defines each of the acronyms separately:

- Information: is the data in paper or digital format. This aspect of ICT concerned about how information is controlled and the meaning and value of information.
- Communication: this aspect includes communication between people personally or electronically located distance apart.
- Information technology: includes softwares, hardwares, and electronic devices which are used for data communication.
- Communication technology: besides components of information technology, communication technology includes protocols to handle data communication.

According to his view, ICT should be used for shortened form for "Information, Communication and Technology".

A simple definition given by Jager and Lokmand[4] defines ICT as a generic term which includes all kind of technologies which are being used for collecting, storing, editing, and passing of information in various forms. On the other hand, a literature study made on ICT proficiency defines ICT as "ICT proficiency is the ability to use digital technology, communication tools, and/or networks appropriately to solve information problems in order to function in an information society. This includes the ability to use technology as a tool to research, organize, evaluate, and communicate information and the possession of a fundamental understanding of the ethical/legal issues surrounding the access and use of information". Both definitions agree on the aspect of ICT as a tool that can be used to insure wisely use and processing of data in an electronic way.

ICT regulator toolkit takes communication aspect of ICT and divides it into two sections. The first aspect deals with Universal Access (UA) where "everyone can get access service somewhere, at a public place, thus also called public, community or shared access". On its second aspect,

communication is meant by Universal service (US) where "every individual or household can have service, using it privately, either at home or increasingly carried with the individual through wireless devices".[6] This aspect of ICT definition shows that ICT mainly assures everyone to have access to all kind of information to assist daily life operations locally or from a distance.

Even though different definitions have been given to the context of ICT, most researchers agree on the point that ICT is the use of all kind of digital technologies that could be used to help individuals, businesses and organizations to wisely use information to enable communication. The technologies involved for communication tend to be complex including radio, television, cellular phones, computers, satellite, wired and wireless communications.

ICT for Millennium Development Goals

Information and communication technology is believed to make a difference in live and livehood of developing countries. ICT4D is one aspect of Information and communication technology which mainly focus on using of ICT solution for development. It also refers to the ways that information and communication technologies can be mobilized in support of the millennium development goals, especially in support of social, economic and political affairs.

United Nation Development Program (UNDP) has set eight comprehensive development goals that the world has agreed upon. These goals are called the Millennium Development Goals (MDGs) which are adopted globally and locally to suit specific development goals of each country. The MDGs has 2015 as a timeline and it includes the following main eight goals[7].:

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender and empower women
- Reduce child mortality
- Improve maternal health
- Combat HIV/AIDs, malaria and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

Previous studies on ICT4D show that ICT has remarkable role to attain millennium development goals. A study[8] made on the role of ICT for achieving MDGs states that MDGs can even be achieved before the timelines by allowing governmental and private organizations to organize ICT capacity building trainings for school teachers to enable them to implement ICT curriculum in the classrooms. Furthermore, the study suggests that government should enhance the implementation of the drawn ICT curriculum for all levels of education including primary and secondary schools.

In line with ICT driven millennium development goals, United Nation ICT Task Force provided computers and communications to poor people all over the world by 2001. The project was aimed to include more than 2 million villages, refugee camps, disaster areas, and recovering war zones[9]. This was an indication that the world has believed the importance of Information and Communication technology and its impact for development.

Phases of ICT4D

Effective management of reliable information which can produce economic return and employment has been a keen to the transformation and upliftment of developing countries economy. Increasingly, many African countries have set Information and Communication Technology as one of the cross-cutting areas by which knowledge engineered economic growth and effective management of information can be attained. Tanzania and Rwanda have set an ambitious national goal that the counties join middle-income economy countries through an ICT led economy[10][11]. It is becoming pivotal for economic growth through its vital contribution to a wide range of disciplines including healthcare, education and good governance. World bank journal relates the impact of ICT on healthcare, education and business services by saying that introducing ICT for those sectors does not mean choosing ICT over healthcare or ICT over education but instead its choosing the most effective way for ICT to help in the delivery of education, healthcare, and other sectors[12].

ICT for development program undergoes different phases before reaching the status it has reached now. The initial phase of ICT4D was started by 1956 in Kolkata at Indian Institute of Statistics when the first digital computer was installed. At that time, the usage of computers was limited to administrative tasks until the emerging of the Internet. The start of the digital technology supplied a new tool to achieve the World Bank's millennium development goals through ICT for development program. This introduces the use of ICT based systems by different governmental and non-governmental organizations more than office administration use[13].

The second phase of ICT4D includes the roll out of telecenters and simple interconnection of computers. Even if this phase has contributed much to the development of the developing regions, the phase couldn't show much progress due to sustainability and scalability problems. Most of ICT4D projects were not well designed to ensure their long term impact in the society. This phase does not also consider an easy way of upgrading the telecenters to new upcoming solutions including infrastructure[13].

The next phase of ICT4D introduces a sustainable infrastructure design by considering telecommunication foundations and power system requirements. Even though infrastructure deign has shown a significant progress, producing network terminals which are affordable by developing countries income level was an issue. The first network equipment that was introduced was a low-spec, low-cost, robust terminals to be used by people of the developing countries. The One Laptop Per Child (OLPC) project[14] is one good example of such terminal. OLPC allows the adoption of affordable educational computers for use in developing countries. After the introduction of this phase, telecommunication infrastructures started to make use of different wireless technologies including VSAT, WiFi and WiMax to provide coverage for rural communities. Wireless technologies were believed to be affordable technologies than wired technologies to provide coverage for rural areas due to geographical nature of the regions. The other innovation at this phase is the introduction of elective power sources. By end of 2007, only 15% of the sub-Saharan Africa was having access to electric power grid[15]. The projects mainly focus on developing low-cost and better ways to store, carry, and transmit electric powers.

2.2. Previous work study on aspect of ICT4D programs

ICT4D is the application of information and communication technology approaches for poverty reduction. Even though, there are substantial variations in the impact of using ICT on efficiency and gross economic growth in different regions, ICT plays a significant role for development. This role can be achieved by adopting different ICT based applications to facilitate activities of various sectors including education, governance and healthcare.

ICT for Education

One of the sectors which can benefit from ICT4D program is education. Education has a vital input to address issues of poverty reduction and healthcare services as stated in the millennium development goals.[16] This involves expansion of primary and secondary education to the needy part of the population. Given limited number of resources, satisfying this demand has been a challenge for many developing countries. Meeting these demands through traditional education system involves hiring teachers at each school levels and equipping schools with adequate educational resources which was found to be unaffordable. ICT provides an alternative solution for providing access to quality of education by optimizing cost and effective use of resources. ICT can facilitate the acquisition of knowledge offering developing countries opportunities to enhance educational systems, and improve policy formulation and execution. One good example to make use of ICT for education is ICT4E Philippines program. The project assumes both private and public companies took responsibility to utilize information technology and mass media in support of education. ICT4E Philippines was built with 38% initiative for ICT infrastructure, of which 70% goes for private companies, and policy component has 23% share. Information technology also enables to give remote classes and to make learning materials to be accessible easily[17].

ICT for Good Governance or E-governance

E-governance is the application of information and communication technology for delivering good governance and customer service. E-governance enables governmental services to be available to citizens in a convenient, efficient and transparent manner. Furthermore, it allows a smooth information flow between the government, citizens and business. Mahbubur and Ahsan define e-governance as “e-governance is the application of electronic means to improve the interactions between the government and citizens and the government and business as well as employ electronic means in internal government operation to simplify and improve democratic government and business aspects of government with the primary goal of boosting administrative efficiency”. It has been a challenge to implement e-governance for developing countries due to absence of infrastructure, resistance to change, lack of education, and electric power shortage. E-governance research work by Mahbubur and Ahsan further proposes adoption of proper affordable infrastructure and development of application as part of e-governance implementation framework[18].

ICT for healthcare or e-health

Almost two.-third of the world’s population is located in developing countries. At the same time developing countries count for a large number of people with high poverty line. This is a good indication that healthcare policies should consider developing countries situation to meet the millennium development goals. Healthcare services should be available to the most rural area of the community where there is demand but little or no supply. It has been a challenge to provide quality of

healthcare for developing countries due to shortage of skilled professionals and lack of adequate medical equipments at each healthcare units. Providing medical equipments and physicians at each of healthcare units does not seem to be affordable solution.

E-health includes all kind of practices supported by electronic and information technology for healthcare services. It enables to create high quality affordable healthcare services for the purpose of online consultation, remote medication, education, and other healthcare services. The setup allows remote healthcare units to benefit from experienced health centers through online consultation and assistance. There are a wide range of applications that could be used as part of healthcare services including electronic medical records, telemedicine, and drug management applications:

- **Electronic health records**: It is an application which enables to store medical history, laboratory results and other relevant information about patients. The stored information can be accessed by physicians to facilitate discussion making and timely service delivery. There are a wide range of EHR applications available including EHRcom[19], openEHR[20], and HL7 Clinical Document Architecture (CDA). A number of standardization efforts have been made to provide interoperability between electronic health record applications. Beside this, much work has been done to enable sharing of patient's medical history that can widely be spread over a number of different healthcare entities[21].

- **Telemedicine**: It is the use of information and communication technology to provide clinical healthcare service from a distance. Telemedicine is more visible for rural communities to improve healthcare service which would not be available due to distance and accessibility of physicians. The government of Pakistan has realized the usage of telemedicine and has planned to build a national telemedicine network[22]. Early stage of telemedicine was started using telephone and radio which was supplemented with video telephony. A number of researches have been done to provide advanced diagnostic support through distributed applications and support for residential healthcare system. Open source applications and residential gateway routers have been developed to support in-home healthcare. The system facilitates seamless migration of patients from hospital to homes while enabling availability of patient's date online. This was achieved through High definition Video Conferencing client, network based medical sensors, and a residential gateway. The residential gateway has healthcare service installed and VPN connection creates a secured connection between patient's home and the remote hospital[23][24][25].

- **Drug management application (DMA)**: Management of scares resources has become vital for developing countries. DMA is an application that runs both on tablet and regular PCs and helps healthcare facilities to keep track of their drug inventory and order new drugs to the respective health authority whenever necessary. The aim of the application is to provide the healthcare facilities with a tool to enhance drug inventory using digital accounting of drug and drug orders. An open source based drug management application was developed by the collaboration of CSD 2011 AGLARBRI team, Karolinska Institute team, and a number of collaborating stakeholders in Africa. The application was designed by taking drug management system of Tanzania and Uganda as a base. The application can be fed with the drug form used in the district and it is able to detect and raise notifications when drug stock levels are low or reaching a threshold level. It provides a solution to the cumbersome and slow task of filling-in paper forms to order new drugs or to keep the drug inventory[26][27].

2.3. Previous work study on ICT4D in Eastern Africa

Rural areas of developing countries count for large number of population size. Most remote and sparsely populated areas are the most likely to be persistently poor and to count for a large number of unskilled labor forces. This can happen due to a number of reasons including resources limitations, separation and remoteness of the regions, low population density, and less business benefit for entrepreneurs. Emerging of small and medium enterprises is important for the economic growth of developing countries including the East African region. Previous researchers have shown that those enterprises are facing several challenges due to limited resources, limited business skill, access to market, less relevant business networks, and SME development. ICT sectors are expected to be major pillars for facilitating this economic growth. Policy makers and nongovernmental entities have invested significant capital to enable growth of ICT sector. Various ICT based solutions have been proposed so that developing countries will be able to cope up with new challenges created due to globalization. Researches made on east Africa's ICT lead economic growth also prove that policy makers are taking ICT as a main tool for development. A research on reduction of information asymmetry reveals that the use of ICT in east Africa is increasing over time.[28] Furthermore, the study states that usage of fixed line and mobile telephony is increasing at a very fast rate. Emerging of such ICT based solutions are believed vital to meet the millennium development goals of the countries. Millennium development goals can only be achieved by adopting ICT based solutions for rural areas to provide access to quality of service and to enable profitable opportunities for economic actors.

Under the umbrella of the millennium development goals, AGLARBRI (African Great Lakes Rural Broadband Research Infrastructure) is exploring the reproducibility, scalability, and extensibility of the positive results obtained in Tanzanian ICT for Rural Development program to countries located alongside the African great lakes region. It aims to build a sustainable rural community networks providing basic public services as a research infrastructure network by activating local communities in rural areas of the African Great Lakes region. The main motivation is to facilitate first mile initiatives to explore and demonstrate methods and solutions that could eventually be used to commercial actors to build production networks in areas where there is demand but little or no supply.

AGLRBRI is a time limited project which runs between October 1, 2011 to September 30, 2013. It addresses rural districts alongside the African great lakes which are emerging in discussion with the government of Tanzania, Kenya, Uganda, Rwanda and DRC with a main focus on e-health services including sentinel surveillance of diseases, secure drug distribution, remote consultations between doctors and co-workers. This requires extension of infrastructure over a dark fiber passing through selected local communities of those countries. Those local communities can be of any service dispensaries which are willing to build their own local area networks.

ICT in Rwanda

As part of the Millennium Development Goal of the World Bank, the government of Rwanda has set an ambitious national goal that the country joins middle-income economy countries by 2020. Science and technology is one of the cross-cutting areas to achieve the goals set by vision 2020 of Rwanda mainly using Information and Communication Technology for Development (ICT4D). ICT4D has a paramount importance to increase efficiency of public services through the application of e-governance, e-health and e-learning principles as it is stated by the NICI plan of Rwanda since 1998[10].

High learning institutions also play a big role for achieving the Rwandan vision 2020 goals by creating trained and educated personnel for the rest of the economy. High learning education in Rwanda is offered by six public, fourteen private universities as well as by a number of specialized public and private institutions. The National University of Rwanda (NUR) and Kigali Institute of Science and Technology (KIST) are particularly noteworthy in terms of ICT education. Connecting those high level institutions through RwEdNet facilitates resource sharing and capacity building between member institutes.

RwEdNet is a non-profit organization with an objective to create a dedicated, cost-effective, and high-performance data network connecting all research and high learning institutions in Rwanda each other. Furthermore, it also enables them to connect to a dedicated global research and education resources network via Ubuntunet, and to the Internet. Some of the main objectives of RwEdNet include:

- National connectivity between RwEdNet members through a dark fiber.
- Upstream connectivity to different REN's through Ubuntunet and to the Internet by commercial operators.
- Local peering with commercial operators at RwEdNet NOC.
- Local Internet Registry services to allocate assigned numbers to member institutes.
- Provide different services to member institutes; such as a national digital repository, video-conferencing services, technical support, training, consultant, etc.

Besides high learning institutions, two healthcare facilities are connected to RwEdNet backbone through a dark fiber. The two connected health facilities, CHUK and KFH, are used as referrals for the province which adds a great value to provide e-health services.

Tanzania ICT4RD

Tanzania is located in the east coast of Africa bordering with Kenya, Mozambique, Malawi, Zambia, Rwanda, Burundi DRC, and Uganda with total coverage of 945087sq km. Tanzania has 21 Internet service provides[30]. The thesis takes benefit from ICT4D Tanzania program which provides broadband connectivity for fifteen villages along the power line between Bunda and Mugumu towns using wireless and fiber optic technologies.
Tanzania has set the third vision called “vision 2025” to attain a high standard of living for its people by eradication of poverty and disease. From the preceding two visions, Tanzania has got a significant progress in the areas of education and healthcare even though there is a concern that the level of progress made does not meet the expectations due to a number of impediments. The 2025 vision mainly aims to achieve a high quality of livelihood for its people and produce a strong and competitive economy. It is envisioned that by 2025 a high quality of livelihood is expected for Tanzanians with a goal to insure the below mentioned standards[29]:

- Universal primary education and eradication of illiteracy
- Gender equality and empowerment of women in all socio-economic and political relations
- Access to quality primary health care for all individuals
- Access to quality reproductive health service for all individuals
- Reduction in infant and mortality rate as low as possible

Tanzania has pin pointed an effective way of avoiding the impediments which introduced a setback to the developments of the previous visions. A number of driving forces which are capable to drive

Tanzania from least developed country to middle income countries has been set. Promotion of Information and communication technologies (ICT) is set as one of the major driving forces for the accomplishment of 2025 vision. ICT is expected to be persistent in all sectors of the economy and should be put to benefit all social groups with a view to fulfill the needs of the people and increase productivity .[29]

ICT4RD has been identified gradually to provide a consorted effort to address issues of affordable connectivity for rural regions of Tanzania. ICT4RD Tanzania is a collaboration project between TCRA, Costech, DIT, Juasun, KTH and SIDA. Besides providing sustainable rural broadband infrastructure network, the main has an insight to identify technologies and technical solutions that can be used to provide broadband network connectivity and ICT services to a rural districts in Tanzania. Furthermore it focuses on providing guidelines on how to design, install, maintain, and operate networks and services meeting technology standards and service needs. The projects mainly aim to improve service sectors efficiency by making information easily accessible in the area of education, health, and governmental sectors. Currently two main sites named Serengeti and Wami are considered by ICT4RD Tanzania project.[30]

2.4. Research gap

Main technical challenges for building ICT4RD solution for rural developing regions includes network connectivity, electric power source, and development of usable applications. Those technical solutions have been addressed by a wide range of ICT4RD projects. For African great lakes region, ICT4RD Tanzania is one good role model. There might still be various solutions proposed by similar ICT4RD projects which may fit for rural areas ICT based solution of developing countries. However, those technical solutions can't be used for new ICT4RD projects due to various reasons. One good example is local regulations for building wireless networks. Some countries have a strict policy that connectivity solutions proposed by one country don't work for other countries. The thesis project tries to enable those factors that need to be considered for a smooth reproducibility of technical solutions provided by ICT4RD Tanzania using a case study.

2.5. Thesis Questions

The thesis answers the basic question:

> Is it possible to reproduce technical solutions proposed by ICT4RD Tanzania to a Rwandan district and the AGLARBRI ring as a whole?"

2.6. Thesis motivation

ICT4D has got a paramount importance for developing countries to build an Internet based solutions. In this regard, ICT4RD Tanzania built a local broadband which pass through fifteen villages around the Serengeti district to benefit health, government and education sectors. There have been a number of discussions between countries locate alongside the African great lakes to build a rural local broadband to benefit rural areas where there is demand but little or no supply. The discussion has passed all the way and become a project called AGLARBRI. At this critical time, it is of technical interests to see if rural regions around the African great lake could benefit from technical solutions proposed by previous similar projects like Tanzanian ICT4RD project. The reproducibility check needs to be performed for both infrastructure and e-health services. The outcome of the thesis gives an insight if positive results achieved by ICT4RD Tanzania can directly be reproduced to a rural district in Rwanda. The outcome also revels if there are any deviations and modification that needs to be performed for smooth infrastructure and e-health service reproducibility.

2.7. Thesis Goal

The main goal of the thesis is to validate the reproducibility, scalability, and extensibility of selected technical methods and results from Tanzanian ICT4D project to a rural district in Rwanda. In this regard, the thesis mainly focus on analyzing those technical solutions for e-health services to one of the selected district in rural district of Rwanda to facilitate the communication between the district hospital and far end health centers with a possibility to connect to the AGLARBRI ring at a later time. Besides making the reproducibility check, the thesis provides a concrete infrastructure design for a rural district in Rwanda considering the outcome of the reproducibility check. Furthermore, it enables factors to be considered for a successful reproducibility of technical solutions proposed by ICT4RD Tanzania for a Rwandan rural district which could be used as an input for future researchers and system developers.

3. Methodology

3.1. A comparative case study methodology

A comparative case study is used as a tool to formulate and address the thesis question. The chosen methodology has two aspects; comparative and case study aspects. The case study aspect of it brings understanding of existing complex systems with a real-event. It enables to extend the experience learned and add strength to what is already known by previous researches and uses it to a new system. Researchers have been using case study research method to address contemporary real-life situation and provide the basis for the application of ideas and experiences and extend the method. Researcher Robert K. Yin defines the case study research method as an "empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used."[31] The comparative aspect helps to compare results obtained by previous researchers with the results of the newly developed system. This deals with detailed contextual analysis of a limited number of events in an analytical or descriptive way.

3.2. Rationale for chosen methodology

The thesis uses comparative case study as a tool to answer the thesis question. This is due to the fact that it provides an in-depth, longitudinal examination of the thesis question through a case while taking previous works as a base for comparison. Technical solutions proposed by ICT4RD Tanzania are used as a base to design a local broadband infrastructure to a rural district in Rwanda as a case. In this regard, the case will enable to analyze proposed technical solutions by ICT4RD Tanzania project and provides a systematic way to look into a new event, collect data, and analyze the information to gain a sharpened understanding of weather the proposed instant can be reproduced successfully. Furthermore, a full infrastructure design to the case is needed to evaluate how good technical solutions proposed by ICT4RD Tanzania meet the service requirement of the Rwandan district. The comparative aspect of the chosen methodology uses a contextual tool to clearly show the deviations whenever infrastructure or service reparability fails.

3.3. Constrains and assumptions

It is common that no ground of generality can be made out of the results obtained due to the number of cases taken. However, case study is still believed to give an optimal result for the research question due to the below mentioned points:

- Considering similarities between the targeted regions and level of development: both countries are under the list of developing countries and by now they both have an ambitious plan to join middle income countries with a focus on ICT led economy.
- Considering the service need to the regions: Both countries are looking into delivering quality of healthcare to rural areas using a joint project, AGLARBRI.

4. Case analysis

4.1. Selecting a case

The reproducibility of technical solutions proposed by ICT4RD Tanzania are validated by identifying interested local communities along the AGLARBRI ring who are willing to commit local resources to build local area networks in their communities. As the selected methodology bases on a comparative case study tool, two districts are selected. The first district would serve as a base where the replication of the second district can be proven on.

The first selected district is Serengeti district from Tanzania. It is selected to be a role model for reproducibility check because it already undergoes a rural local broadband infrastructure to improve service sectors efficiency by making information easily accessible in the area of education, health, and governmental sectors. The other advantage of selecting Tanzania as a role model is that the two countries have a common undergoing project called AGLARBRI. The project aims to connect rural districts of five countries around the African great lakes region, including Tanzania and Rwanda, to build a local broadband infrastructure network. The other last point for choosing Tanzanian district as a role model is that the two countries are members of the east African community and have many cultural similarities. Previous studies[32] in the area of ICT4RD shows that socio-economic activities have an impact on adaptation of ICT based solutions and service requirement.

The second district was selected from Rwandan side. The main purpose of selecting second district for this thesis is to replicate technical solutions proposed by ICT4RD Tanzania and list out the deviations if there are any. With the same reason taken for selecting Tanzania, Rwanda was selected to check for the reproducibility check. Rwandan Ministry of Health helped by providing valuable information containing the facilities for district hospitals and health centers in Rwanda. Based on the provided information, two districts were selected from Rwandan side: Nagoma and Kirehe districts. While making first phase site-survey, it was found that there was a local project already running at Nigoma district and hence only Kirehe district was able to proceed to the next stage of the project. This was due to the fact that AGLARBRI has a prerequisite for member connecting end-nodes to atleast have a functioning local broadband which can further be connected to the ring. Nigoma district was at its initial states and was not ready enough to connect. As there was also an interest to make the selected district part of the AGLARBRI ring, Kirehe district has shown geographical advantage to demonstrate enter-country interconnections as it is bordering to Tanzania at Rusumo border post.

4.2. E-health services in Rwanda

By end of 2011, Rwanda had about 366 health centers, 33 district hospitals and 5 referral hospitals. Beside those healthcare facilities, there are a large number of health posts which are located in proximity distance to rural communities. The work flow is that health posts and health centers are controlled by their respective district hospitals including for referrals. The referral hospitals located in Kigali provide referral service for the province. Most of the district hospitals in Rwanda are connected to the dark fiber and national electric power grid. Connectivity of health centers and health posts to the Internet and electric power grid is still remained an issue. Health information technology in Rwanda is showing drastic progress with the participation of different stakeholders. Particularly in areas of

electronic health recording and reporting system, Rwanda still remained a pioneer for the region. This fledging industry is mainly led by the Government of Rwanda as the private market is not involved into it yet. Even if some of them are at their early beginning, the main entities which are currently involved in electronic based health service in Rwanda are OpenMRS, TracPlus and TRACnet, CAMERWA, Telemedicine, Health Management Information Systems(HMIS), Mutuelles program, and e-learning.

OpenMRS (Open Medical Recording System) is an open source flexible electronic medical recording platform which can give service to clinical and research organizations. It was used by health partners and Columbia University's Millennium Village Project(MVP) and has been endorsed by government of Rwanda for national rollout.

TracPlus and TRACnet: The application is used by the government of Rwanda to collect monthly report from facilities providing ART to patients. The application is used by a research center located in Kigali.

HMIS: It is Microsoft access based database system implemented by the Ministry of health to integrate data collection, processing, reporting and use of information necessary for improving health service effectiveness and efficiency through better management at all levels of health services. The system is still paper based on health centers and health post level and with a combination of paper and electronic reporting on district level.

Camerwa: is a non-profit organization which manages the country's drug inventory. It uses the information received from TRACnet and health facilities to aggregate clinic-level information on the number of HIV, TB, and other epidemics seen in a given period to manage the drug and medical supply purchases for the country. It also procures and distributes all other essential drugs and medical consumables.

Mutuelles program: is a Microsoft access based database to store information about patient health utilization for payment purposes and health insurances.

Even though there are a number of tools to administer health care services, there is no any integration of the various systems made so far. The government of Rwanda overhauls the HMIS system but system level improvement is expected to resolve and much work is still remained untouched. Network coverage and electric power grid are still on the district level.

4.3. E-health service in Tanzania: Serengeti Site

Serengeti is located at the northern-west part of Tanzania. The site aims to connect two district headquarters of Bund and Serengeti through a dark fiber link of 140km long provided by TANESCO. The link passes through fifteen villages between the cities with a terminal at Nata. ICT4RD program uses those fibers to build a gigabit local broadband with a possibility of building access networks along the line.

The main motivation behind connecting rural networks was to link them together to increase availability and accessibility of information especially for public service sectors. There are a number of options to achieve this which mainly depend on cost, accessibility, reliability, data rate, geographical

location, and environmental factors. Depending on those factors a rural area network can have microwave links, WiMax, satellite links, WiFi link and optical fiber links. The master thesis done by Zachariah Isamuyo concludes that a combination of those technologies would be most appropriate for rural districts of Tanzania to meet the service need.[33]

To provide network connectivity infrastructure, Serengeti site uses fiber-wireless technologies. This is because there are some rural areas which are not under the reachability of the fiber link. The second main reason was optical-only network introduces high deployment and maintenance cost to draw the fiber to every rural sector. Integrating the fiber technology with a wireless has shown an incredible decrease in total project cost and an easy way to reach all rural sectors. WiFi was considered as the most affordable solution than any of the above mentioned wireless technologies to work with rural areas.[33]

4.4. Stakeholder analysis

Analysis of stakeholders is performed by a power-interest grid. The grid evaluates the impact and interest of the stakeholders on the outcome of the project. The stakeholder can normally be grouped in four classes:

- **Manage:** these groups of stakeholders are fully interested to engage full time on the project and have power to create impact on the outcome of the project. As those stakeholders have huge impact up to the point that may lead to failure of the project, a great care needs to be taken to get a high success rate. Stakeholders on this group include REHCE (Regional eHealth Center of Excellence), Ministry of Health of Rwanda, and The Swedish Program for ICT in Developing Regions (SPIDER). REHCE serves as a regional facility for countries in the great lakes region. It mainly focuses on achieving excellence in health informatics with community driven healthcare education and research projects. REHCE is grouped under this group because it is the entity which heads the AGLARBRI project. SPIDER is also grouped under the manage group. SPIDER is used as the main income source for the project. It is grouped under this group because, SPIDER has shown a big interest for the couple of years to enable development plans trough ICT for developing countries. On the other hand, getting fund from organizations like spider is paramount go get success for the project. Ministry of Health, Rwanda is also under the manage group because it has the power to mandate healthcare projects in Rwanda.

Figure-1 shows the aforementioned stakeholder analysis:

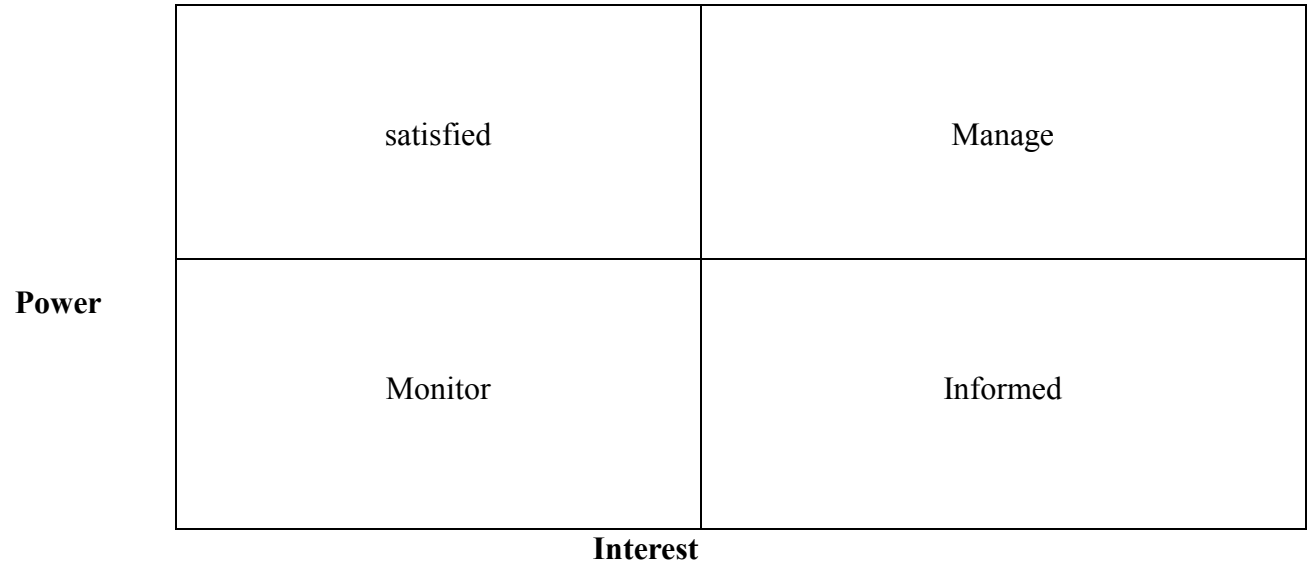


Figure-1 stakeholder analyzer diagram

- **Informed:** These groups of stakeholders have high interest but they don't have power to create impact on the outcome of the project. Stakeholders which are under this group provide an input to the success of the project in one way or the other even though they are under control of the managed stakeholder groups. Stakeholders under this group include high learning institutions, district hospitals, health centers, health posts, and patients. Part of high learning institutions which are under this group include Kigali Institute of Technology (KIST), National University of Rwanda (NUR), Royal Institute of Technology (KTH), and Karolinska Institute (KI). Those institutes have shown high interest to see the outcome of the project and contribute with technical support for the success of the project. District hospitals, health centers, health posts, and patients are also grouped under this group because they have high interest to see the outcome of the project as being last user beneficiaries.
- **Satisfied:** Stakeholders under this group have high influential power for the outcome of the project even if they are less interested. This group of stakeholders should be considered well as they may lead to a final failure to project. Regulatory offices (like RURA) and RDB are grouped under this group. Rwandan Utilities Regulatory Agency has the mandate to regulate telecommunication sectors, enhance and develop service in compliance with most advanced technology and also ensures telecommunication infrastructures have no adverse impacts on the environment. That mean, the regulator has power to mandate telecommunication infrastructure builds around the region. Rwandan Development Board, on the other hand, operates with an aim to create an open business environment in Rwanda. Both stakeholders have a high impact to the outcome of the project since building a rural infrastructure network needs initial approval from the stakeholders before excision.
- **Monitor:** These groups of stakeholders have less impact on the outcome of the project yet interest. The stakeholders may not have much power on the outcome of the project but will have part somewhere in the project life time when ever needed to look for options and opportunities. MTN, Tigo and BSC are grouped under this stakeholder groups. MTN and Tigo are telecom service providers in Rwandan. Those telecom providers contribute to the outcome

of the project by providing infrastructures including towers and masts to be available for the project if needed. On the other hand, BSC mandates innovative ICT solutions based on broadband connectivity using fiber-optic networks in Rwanda. Whenever fiber connections are needed for the project at any phase in the project lifetime, BSC needs to be contacted.

4.5. Aim of data collection

Intensive site surveys for Kirehe district from Rwanda and system analysis for Serengeti district from Tanzania were made. The aim of the data collection can be seen from infrastructure and service reproducibility check point of view. Infrastructure reproducibility check mainly focuses on the following points as a main goal:

- **Analyze ICT4RD Tanzania proposed technical solutions:** This part of the study mainly focus on finding technical solutions proposed by ICT4RD Tanzania. Once the analysis of proposed technical solutions is listed out, the same solution will be used to design a local broadband for Kirehe district in Rwanda. If the same technologies used by ICT4RD Tanzania can be used to build local broadband in Rwanda, it means that the reproducibility of the technology is possible. On the other hand, a failure can help not only to see direct replication are not possible but also to identify things that needs to be considered for smooth technology replication between the two districts. The analysis needs to be made for infrastructure and e-health application wise:

    - **List out infrastructure technologies:** The first aim of this study is to make extensive study about the proposed technical solutions by ICT4RD Tanzania project. The outcome of the study is used to make a list of technologies used by ICT4RD Tanzania and prepare them for replicating to Kirehe network design.

- **Analyze existing facilities for Kirehe district healthcare units**: the first main goal of the site survey and interview is to check on existing facilities for Kirehe district healthcare facility. This includes checking availability of electric power, lightning protection system, and Internet connectivity. This information helps to check the necessity of those infrastructures for the district's healthcare infrastructure design. If those infrastructures are not currently available, proposed technical solutions from ICT4RD Tanzania will be used. If those infrastructures already exist in Kirehe district healthcare facility, the question would be optimization and adding performance to an existing system.

- **Analyze telecom regulatory policies for Rwanda:** Usage of telecommunication infrastructures including wireless systems, towers, masts, and VSAT base stations is mainly influenced by local regulations. Alongside with the network design, the outcome of thesis study will make sure that network infrastructure is built considering local regulations by making use of existing towers and masts from ISPs.

Services analysis from Rwanda and Tanzania district is made with the following points as main objectives:

- **List out e-health services from ICT4RD Tanzania project:** this part of the study enables to list out the services used by ICT4RD Tanzania project and propose them for use to Kirehe district e-health service build. This information will provide if there are services which are

applicable for both Kirehe and Serengeti districts. This also gives a wider impression that some services are more needed than other services for rural healthcare service. Whenever services found to applicable for both districts, services in use by ICT4RD Tanzania would be checked if it's possible to replicate them to Kirehe district.

- **List out challenges that Kirehe district healthcare service facing**: The other purpose of the site survey and interview is to investigate the challenges the district healthcare service is facing. The main idea behind the survey is to know what problem the district is facing and find out what ICT based solutions can be proposed. Related to the thesis question, this information helps to gather what services are relevant from Kirehe district healthcare service perspective. Furthermore, based on the identified services, service reproducibility check can also be made.

- **Drug Management Application analysis**: the other purpose of the site survey was to install DMA application developed by Karolinska institute and KTH CSD team locally at Kirehe district hospital. The main outcome of this method is to understand the work flow for drug management system in Rwanda. As the drug management application is mainly developed using drug management system of Tanzania and Uganda as a base, this information would be vital to identify drug management work flow differences between the countries. Furthermore, the outcome of the research answers the basic thesis question if the developed application can be replicated without any change to Rwanda drug management system. It also enables to pin point if there are any deviations and propose recommendations for smooth service replication.

4.6. Data collection tools

Study on Tanzanian ICT4RD Technical solutions

The thesis primarily tries to validate the reproducibility of positive results obtained by ICT4RD Tanzania to a Rwandan district and also to similar rural districts of the AGLARBRI ring. To validate this reproducibility, it is vital to first list out what technologies have been used by ICT4RD Tanzania. Intensive study on ICT4RD Tanzania technical solutions have been made to understand ICT4RD Tanzania in depth. The study was performed for both infrastructure design and available healthcare services. Once those proposed technical solutions are listed out, the reproducibility check is made by using the same technologies for Kirehe district infrastructure design. This method helps to essentially list out the deviations that could exist mainly for infrastructure and service design. It should however be noted that fully reproducibility check can only be made by also considering factors like socio-economic and work flow analysis of administrative service sectors as it is discussed shortly. In short words, full reproducibility check can be made by backing up technical analyses made for ICT4RD Tanzania with work flow and service need requirements of Kirehe district.

Gathering data: Technical site surveys, infrastructure design and questionnaires

The next step after listing technical solutions proposed by ICT4RD Tanzania was to map those proposed technical solutions to a Rwandan district. However, the mapping should be done considering existing network infrastructure of Kirehe district, local regulations, and its healthcare service demands. This pre-study is accomplished by making an intensive site survey, interviews, designing a broadband for Kirehe district, and questionnaires. Making a site survey was found to be a very challenging task due to a number of reasons. It is helpful to travel with people who speak the local language (iKinyarwanda) to facilitate the task.

The infrastructure check includes analyses for availability of local internet connection, electricity, and lightning protection system for Kirehe district. Checking availability of those resources is needed to determine which equipments are required to build a local broadband for Kirehe district. Whenever those equipments are not available at any of the district healthcare units, similar technologies from ICT4RD Tanzania will be used to design a local broadband for Kirehe district and make the reproducibility check. Whenever the technology mapped from ICT4RD Tanzania to Kirehe district healthcare facility is not meeting the service requirement of the district, technology requirement deviations will be noted. If the same technology used by ICT4RD Tanzania is used to provide a local e-health broadband infrastructure, success in reproducibility will be reported. The outcome of the report can lead to make a slight generalization and list out the requirements to build a rural broadband infrastructure network. The question is how is it possible to validate if the designed infrastructure network indeed provides intended coverage for the Kirehe district after using the same technologies for from ICT4RD Tanzania. Radio mobile is used for this purpose.

Radio mobile is a radio propagation simulation program by making use of map of a specified area. It is used to simulate radio coverage for Kirehe district by specifying GPS coordinates of the health care units. Radios mobile is used to analyze and validate the reproduced network design using fiber-wireless technology. It uses a predefined radio equipment specification to make the simulation. Ubiquiti wireless equipment with specification of 27dBm radio transmitter, worst case receiver sensitivity of -96dBm, 20meters base station tower height and user side subscribe unit height of 2meter is selected to make the simulation for Radio mobile.[34] Dish and sector antennas are used wherever applicable.[35][46] Ubiquiti wireless equipments specification has been used for simulating the wireless coverage because it provides a reasonable coverage at affordable price.

The service need requirement analysis takes benefit from the list of applications proposed by ICT4RD Tanzania and evaluates if those services have magnifying benefit from Kirehe district e-health facilities perspective. Questionnaires and interviews are used to determine the service requirement of Kirehe district healthcare facilities. Once the data from Kirehe district is collected, it leads to the conclusion what services are needed to facilitate e-health service for the district. The outcome of this service requirement can further be used to check with available services for ICT4RD Tanzania. Whenever there are similar applications used by both districts, the application used by ICT4RD Tanzania will be checked if it could be used by Kirehe district. If the application used by ICT4RD Tanzania can be used by Kirehe district healthcare service, reproducibility of application will be reported. If there is a failure in using the application, reproducibility of the application will be noted. Furthermore, this service analysis can provide information about services which are essential to build a rural healthcare facility. On the contrary, there might be cases that applications make use only for one district but not for other.

Service deployment for DMA with questionnaires

DMA (Drug Management Application) is an application which is developed to keep track of healthcare centers drug inventory and orders. The application is a result of a collaborative project between different stakeholders basing Tanzanian and Ugandan drug management system as a base. For a Rwandan district to make use of this application, intensive analysis and work flow analysis needs to be done. It could be possible to explain what the application can do for local pharmacists and check with them if the application can fit with their work flow but this will not give them a better look of the application. The best way to investigate whether the application fits the best from Rwandan perspective

is to install the application at the district hospital and collect feedback from the physicians and pharmacists. Due to this reason, a different method is used to make reproducibility check for DMA application. Once the application is installed at Kirehe district, questionnaires and informal discussions with pharmacists are used to collect feedbacks. Beside this, work flow for drug management system for Rwanda is analyzed. The output of the two methods will be used to make decision if the DMA application developed basing Tanzanian and Ugandan system could be directly used for a Rwandan drug management system. Whenever there is a difference between the features of the drug management application and the feedback from medical expertise or drug management work flow, the deviation will be reported for further customization and development. Similar workflow analysis results allow the application to be used without customization.

Official documents and interviews for local regulation check

Reproducing ICT4RD Tanzania technical solution to a Rwandan district is also affected by the difference in socio-economic activities and healthcare challenges that the two countries facing. Furthermore, local regulatory rules and workflow analysis of the service sectors also have an impact on how infrastructure and services can be build. In other words, a developed infrastructure or service design should reflect those factors into account.

Local regulation of the districts in Rwanda and Tanzania can be different which would affect infrastructure designs. For example a regulator can set what frequency range, maximum power, and coverage limitations a wireless network design should meet. Making an interview and arranging formal discussions with regulators allows addressing these issues. Whenever there is regulatory difference between Rwanda and Tanzania, the network design should reflect the difference and amendments needs to be done accordingly. If there are no regulatory differences between the two countries, direct reproducibility of technologies to Kirehe district will be possible. The outcome of this method helps to generally show the impact of stakeholders for building rural local broadband infrastructure.

5. Results

5.1. Study results for ICT4RD Tanzania

This section describes the outcome of the intensive study made on technical solutions proposed by ICT4RD Tanzania.

Generally speaking ICT4RD Tanzania program has two sections. The first section of the program deals with infrastructure design while the second one mainly enables usable e-health services. The infrastructure is built by using Tanzanian Electric Supply Company (TANESCO) fiber optic cable installed along its power line running from Bunda to Serengeti district. The fiber is about 140 kilometers long and crosses 15 villages. The fiber is attached on top of TANESCO poles carrying utility power from Bunda to Mugumu. The cable is terminated into optical distribution frame (ODF) at Fort Ikoma, Bunda, Nata and Mugumu stations. Point of Presence at the stations provides connectivity to a VSAT, fiber and/or wireless networks. This scenario enables network coverage for villages alongside the fiber line through the wifi links.

A Cisco switch with atleast two slots for optical transceiver and ports for fast Ethernet RJ45 ports is installed at the Point of Presences. The transceiver module is capable of transmitting optical signal up to 80km depending on the total segment loss. Two SC-FC fiber patch cords connect transmit (Tx) and receive (Rx) ports of the transceiver module to the ODF to light two fiber strands. The switch is then connected to VSAT and wireless access points installed at the substation through STP/UTP cables. A VSAT installed at the stations provide 128 kbps Internet connectivity to all clients connected to the Serengeti broadband project. The wireless access point at the substations provides connectivity to the fiber network to all wireless clients installed.

Access network connection

ICT4RD Serengeti research project focus on connecting health centers, governmental offices, and educational sectors along the fiber line to enable utilization and facilitation of e-learning, e-government, and e-health services. The project prefers connecting those sectors along the Bunda-Mugumu line through a wireless connection than a fiber link due to lack of budget and technical challenges as those sectors are very dispersed. Unlicensed frequency range of 2.4 GHz and 5.8 GHz are used. Three access points were installed at Bunda, Nata, and Mugumu to provide connectivity to wireless clients installed at schools, health centers, and local government offices within the area. The access points were further connected to the fiber line allowing intercommunication to all installed wireless clients at Bunda, Nata, and Mugumu.[37]

Sector antennas covering 1800 with a gain of 15dBi were used to provide network coverage. LMR400 N/M to N/M cables connect the antenna to a lightening arrestor N/F to N/F, then another LMR400 N/M to N/M cable connects the lightening arrestor to the radio. The radio act as an access point (AP) and can provides input radio power of 50mW, 100mW, 200mW, or 400mW. Shielded twisted Pair (STP) cable connects the PoE(Power over Ethernet)radio to the DC-Injector. The DC-Injector receives power from power adapter connected to UPS. STP cable connects the DC-Injector to RJ45 port of the D-link switch which can further be connected to the local LAN.

Routing

Routing for the ICT4RD Tanzania is performed using bifrost routers. The birfrost router handles layer-3 routing, iptable firewall, openvpn and NAT. The layer-3 routing facilitates the communication between the local LAN and the outside world. Iptables will be used to provide network security, filtering and traffic shaping. As the system could be used for healthcare facilities, a secured way of connecting to a remote host is one of the requirements. This is achieved through OPENVPN. NAT (Network Address Transition) can be of two types: SNAT and DNAT. SNAT enables the nodes connected to the local LAN to reach the internet. Using DNAT, a local computer in local LAN can have a private IP address and also reachable from outside world. This also helps to mitigate network attacks from a central point by hiding servers with public IP addresses from being world traceable.

Tower construction

Two communication towers were built and installed at Manyamanyama and Mugumu. Both towers host wireless equipments to enable line of sight communication with CPE clients on another site. Each tower is 30meters tall with three legged steel bar structured. It is composed of ten 10feet sections and was built to carry radio equipment, antennas and lighting protection road. The head section of the tower has a triangular plate as its top and a metal bar is attached at the center of the plate for holding lightning rod. The tower is supported by three groups of five steel stay-cables placed 120^0 to each other, and attached on hooks buried in the ground with concrete support.

Lightning protection for towers

Three holes were dug close to each of the towers with 120^0 spacing between them. Each of them is 1.5meters deep and 1meter in diameter. To lower soil resistance, all holes were filled with moisturized soil, charcoal dust, salt and water mixed together. In each hole, five pure copper earth rods of 1.2 meters length and 1.5cm diameter connected in parallel were buried. The earthling rods in each hole were in turn connected through dug trenches to form a common ground. A lightning rod was attached at the top of the tower. A thick copper cable with one end connected to the top terminal rod was run all the way to the tail section of the tower and connected at a common ground.

Electric Power source

As the fiber is hosted on TANESCO poles, Bunda, Nata and Mugumu stations have electric power grid source installed. Backup power at all Points of Presence is provided using an Inverter/Charger and a set of deep cycle batteries. Inverter/Charger charges batteries when general power is available, otherwise inverts DC from the batteries to AC to power equipments.

Services

Beside the built infrastructures, a number of services have been proposed to facilitate healthcare facility for Serengeti district. Telemedicine, webmail, domain name and web services are some of them:

Telemedicine: The main purpose to install telemedicine application at Serengeti district was to enable doctors at the district hospitals to be able to give online consultation to clinical and health officer at the health centers. Doctors situated at Nyerere district hospital were able to give consultation for clinical officers located at Nata health centers through telemedicine applications. This helps to mitigate

shortage of medical doctors and physicians which could not be available at the health center level. A successful telemedicine service needs video conferencing client, camera, speaker, and Ethernet based medical equipments. The whole video conferencing set needs to be installed on both sides of the communicating parties. There are also some scenarios where by more than two parties participate telemedicine conferences simultaneously.

Webmail: It is an application which can be built by a corporate network to facilitate exchange of digital messaging service. Web based email service was developed to be used by people working on health sectors. The application was developed using postfix (SMTP), dovecot (IMAP/POP), and sqiorrMail (web mail). For local email service, users need to have computers connected through a wired/wireless network. Sending email outside of the local network needs uplink connection to the Internet.

Local Voice Services: It is an IP telephony system which is mainly used to help telemedicine service. It is built based on SIP Express Router (SER). SER is a high performance and an open source server which can operate as a SIP registrar, proxy or redirect server. It has a number of features with an application-server interface, presence support, SMS gateway, Radius and syslog accounting and authorization, server status monitoring and security.[34]

Network Services:

- **Domain Name System (DNS):** DNS was built to handle name to IP and vice versa resolutions for the district. It is built based on BIND9.
- **Web service:** Appach2 web server has been configured with SSL support and backend MySQL server to host web applications.
- **DHCP (Dynamic Host Configuration Protocol):** DHCP was installed to dynamically provide IP address for the local broadband.

5.2. Result for Technical site survey and questionnaires

A number of technical site surveys were accomplished for Kirehe district.

There are fourteen health centers for Kirehe district and the district hospital is located at the district's head quarter. Besides the district hospitals and health centers, there are a number of health posts located close distances to the rural community. Current status of the districts is collected using the questionnaire attached on appendix-C questionnaire-A and also backed up with on-site survey. The result of the data collected is shown in figure-2.

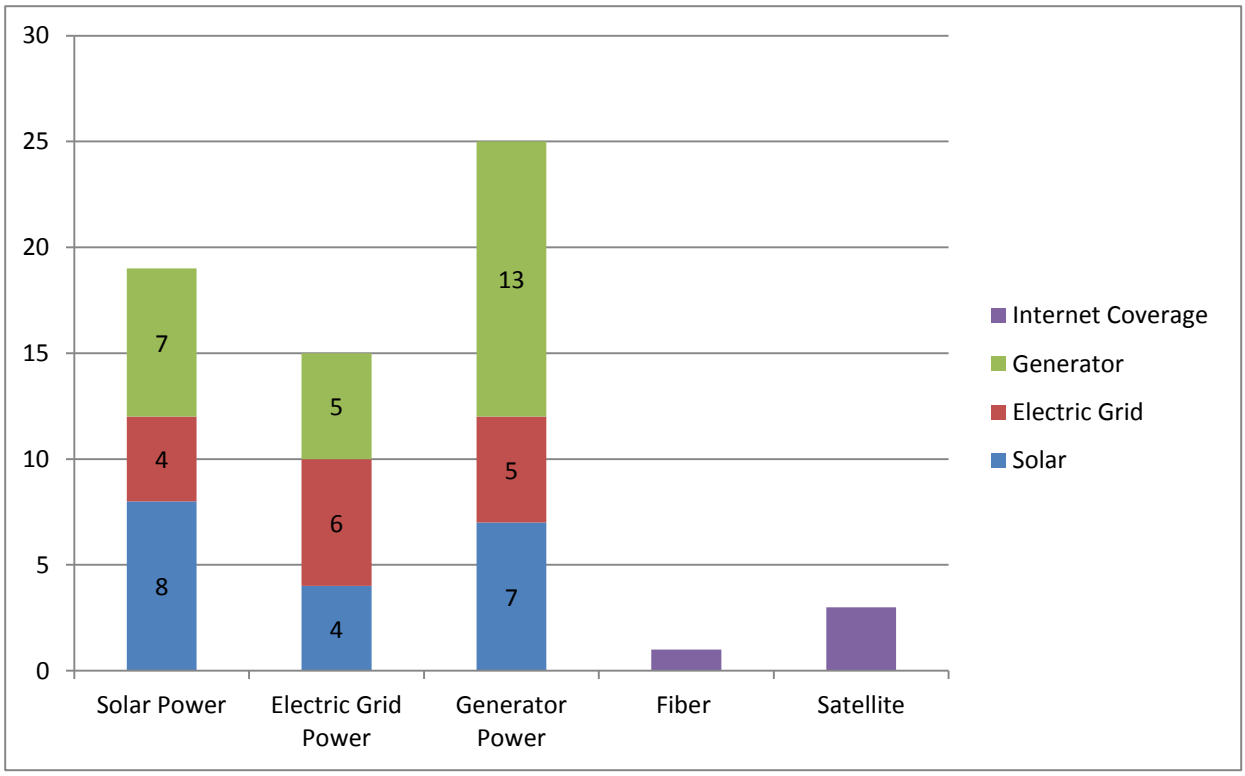


Figure-2 electric power and internet coverage for Kirehe district health care units

As shown on figure- , 57% of the health centers have solar power, 35% of them have electric power grid and 92% of the total health centers have generator power as a backup. Health centers with electric power grid or solar power use generator power as a backup power source. This shows that generator power is the most used backup power source for the district.

- Out of eight health centers which have solar power, four of them are connected to electric power grid and seven of them have generator power connected.
- Out of six health centers connected to electric power grid, four of them have solar and five of them as generator as a backup power source.
- Out of thirteen health centers, five of them are connected to electric power grid while seven of them have solar power system installed.

On the other hand, it is only the district hospital which is currently equipped with a broadband Internet connection with a fiber link. 23% of the health centers have a VSAT link which is setup by their partners to report HIV patients record.

5.3. Result for Infrastructure design

Kirehe district is located in the eastern province of Rwanda, approximately 130km away from Kigali city. The district has a hilly geographical nature with Tanzania as its boarder at Rusumo border post. Besides a number of health posts, the district has fourteen health centers and one district hospital located at the district headquarters. Due to hilly geographical nature of the district, site-survey to each of the health centers was performed. Table-1 shows the coordinates for the district's healthcare units.

No	Name of HC	Coordinates
1	Gahara HC	-2.33450 , 30.50427
2	Gashongora HC	-2.31787 , 30.55071
3	Musaza HC	-2.33103 , 30.62853
4	Bukora HC	-2.30888 , 30.78652
5	Rusumo HC	-2.28342 , 30.75603
6	Nyabitare HC	-2.21390 , 30.79453
7	Nyarubuye HC	-2.17363 , 30.75833
8	Nasho HC	-2.13042 , 30.85173
9	Kabuye Dispensary	-2.08765 , 30.77795
10	Mulindi HC	-2.10320 , 30.69223
11	Ntaruka HC	-2.14432 , 30.69068
12	Kirehe HC	-2.26663 , 30.65359
13	Mushikili Dispensary	N/A
14	Kirehe DC	-2.26663 , 30.65359

Table-1 coordinates for Kirehe district healthcare facilities

Kirehe district hospital is where the optical fiber for the district is residing. The optical fiber is terminated at the data center of the district using Cisco 3560 Layer-3 switch. Currently the district hospital network and system administration is handled by RDB. The layer three switch is used as a DHCP server to provide IP address and also performs Network Address Translation (NAT). The broadband internet connection from the district hospital gives internet access for the users mostly through a wireless connection.

Unlicensed frequency range with frequency hopping is used as it was communicated with RURA. Generally speaking there are two types of interconnections for the whole design. The first one is base-

station to base-station interconnection which is achieved through a long range point-to-point (line of sight communication) link. Three base stations have been selected at three different places whose coordinates are described at table-2. Once the signal reaches at a nearby base station to the hospitals, a 120^0 sector antennas are used. The second type of interconnection provides coverage not only for healthcare units but also for educational sectors, dispensaries and governmental sectors located at the antennas' coverage boundary. Most of the ISPs in Rwanda relay on unlicensed frequency range and hence the network design lowers the signal level as low as possible on the major towns to mitigate possible interferences and jamming. The design includes total power consumptions and weight calculation mainly for base stations which can be used while hosting the wireless equipments on ISP towers/masts.

Three base station repeater sites are proposed to provide coverage for nearby hospitals and service sectors. The requirement on the health centers is similar. A subscriber unit needs to be installed at the health centers to receive the wireless signal distributed by the base stations and connect it to their local network through a layer two switch. The subscriber unit can be placed at the top of the building by placing a long rod which is not longer than 7meters as stated by RURA.[3] The interconnection from outdoor subscriber unit to indoor switch is shown in figure-3.

Number	**Base station Name**	**Coordinate**
1	Kirehe DH base station	-2.26663 , 30.65359
2	Nyabimuri base station	-2.157263 , 30.78082
3	Nyamugali base station	-2.308063 , 30.7512

Table-2 coordinates for base station repeaters

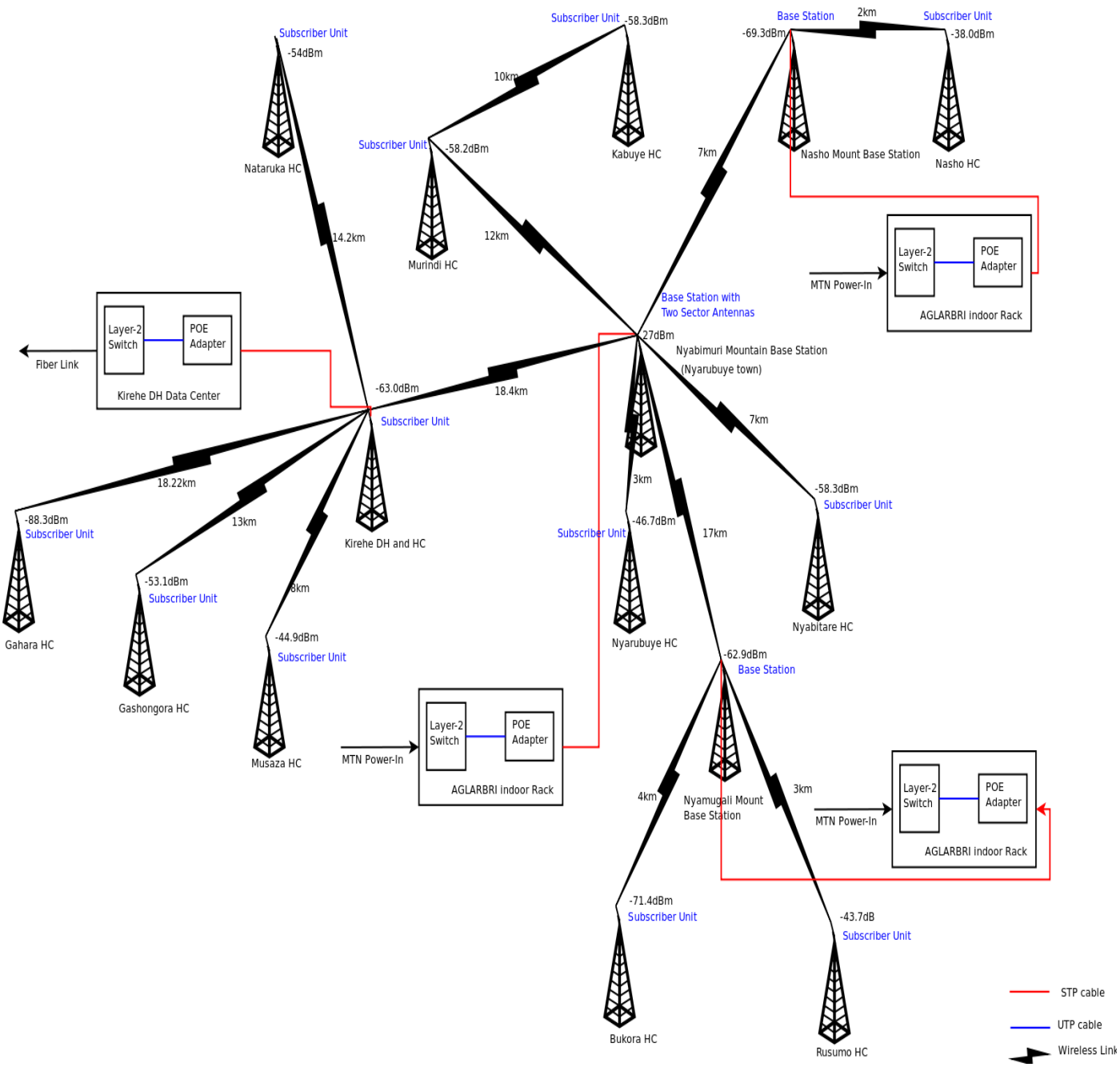


Figure-3 Infrastructure link between Kirehe district hospital to its thirteen health centers.

Radio mobile simulation analysis for the district network design is shown in table-3:

Base station name	**Receiver sensitivity**
Gahara HC	-88.3 dBm
Gashongora HC	-53.1 dBm
Musaza HC	-44.9 dBm
Bukora HC	-71.4 dBm
Rusumo HC	-43.7 dBm
Nyabitare HC	-58.3dBm
Nyarubuye HC	-46.7 dBm
Nasho HC	-38.0 dBm
Kabuye Dispensary	-58.3 dBm
Mulindi HC	-58.2 dBm
Ntaruka HC	-54.0 dBm
Kirehe HC	-63.0 dBm
Kirehe DC	-63.0 dBm
Nasho Mount Bash Station	-69.3 dBm
Nyamugali Mount Base station	-62.9 dBm

Table-3 receiver sensitivity output from Radio Mobile

Figure-4 demonstrates the wireless signal coverage for Kirehe district health care unit.

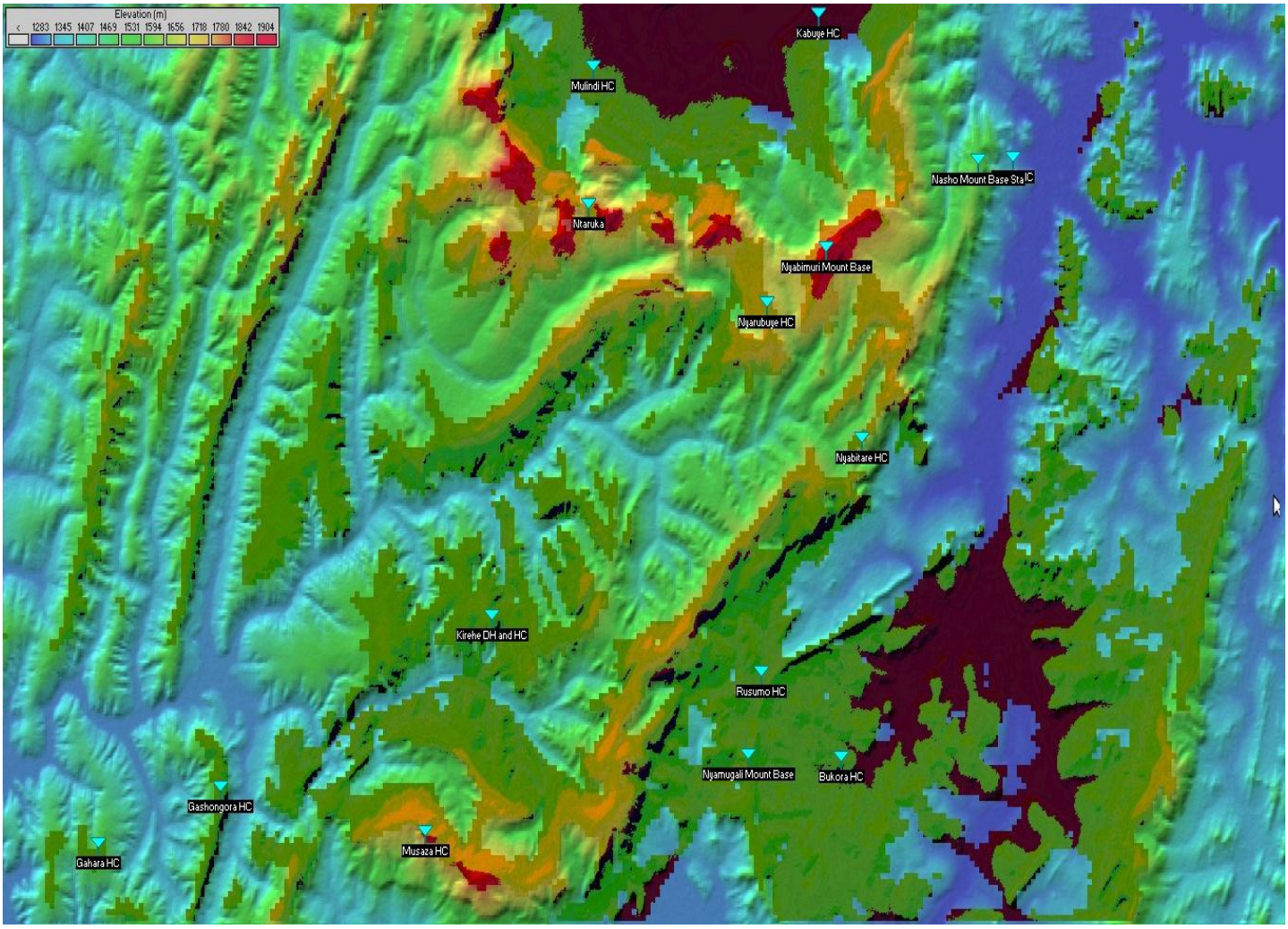


Figure-4 Radio mobile simulation output for Kirehe district health care units

The output of the simulation revels that all the health facilities have full reachability.

Lightning strike protection system for health centers

The site survey also reveals that none of the health centers have lightning protection installed.

Lightning strike protection system needs to be installed in compliance with national safety standards maintained by the national fire protection association (NFPA 780) and Underwriters Laboratories (UL96A) to attain a safe outdoor wireless system. The lightning strike protection system incorporates three main components: roof-top air terminal, down conductors and connecting rod to interconnecting the air and the ground terminals. Both the air terminal and down conductor should be made from pure copper. In addition to protecting outdoor wireless equipments, the lightning strike protection system should protect indoor equipments such as switches and server rooms. To achieve this, an appropriate place should be selected depending on the structure of the roofs. The two types of roof structures faced for Kirehe district health centers are flat and gently sloping roofs. To avoid violation to standards and provide full protection, flat and gently sloping roofs with an edge should have a rod holding both the wireless equipment and the lightning protection air terminal placed within two feet from the ridge end.

The rod should be placed at the building where the server room of the health center is situated or it should be within 50feet diameter range from the rod. Figure-5 illustrates this in more detail.

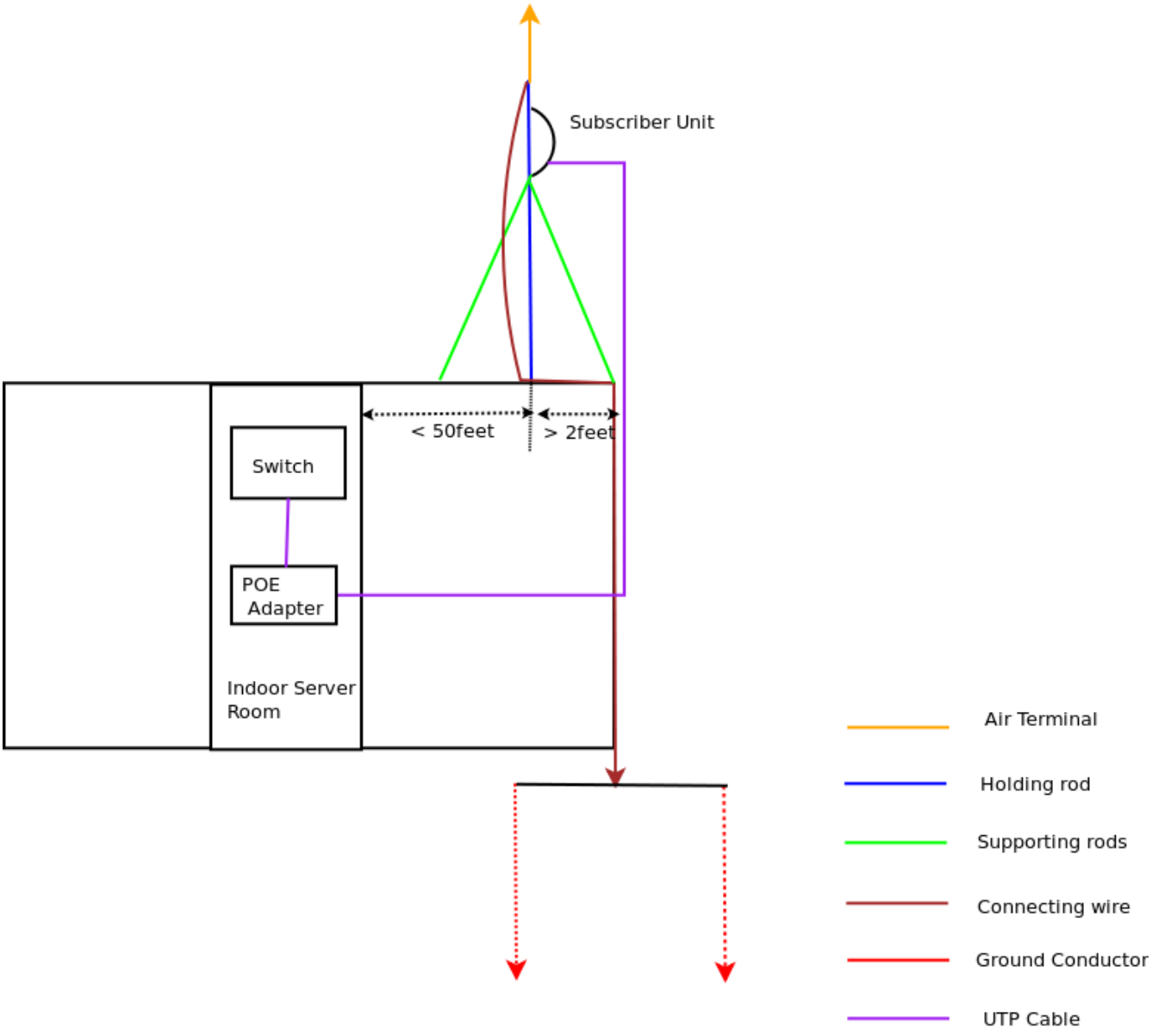


Figure-5 Lighting protection system and subscriber unit interconnection for health centers

To provide ground termination a hole needs to dig with an average of 1meter deep and 0.5meter diameter. Two pure copper grounding rods each with 1meter long should be buried and connected to form a common ground. To lower the soil resistance, the hole should be filled with moisture soil, charcoal, salt and water. Figure-6 shows the exact demonstrates of this.

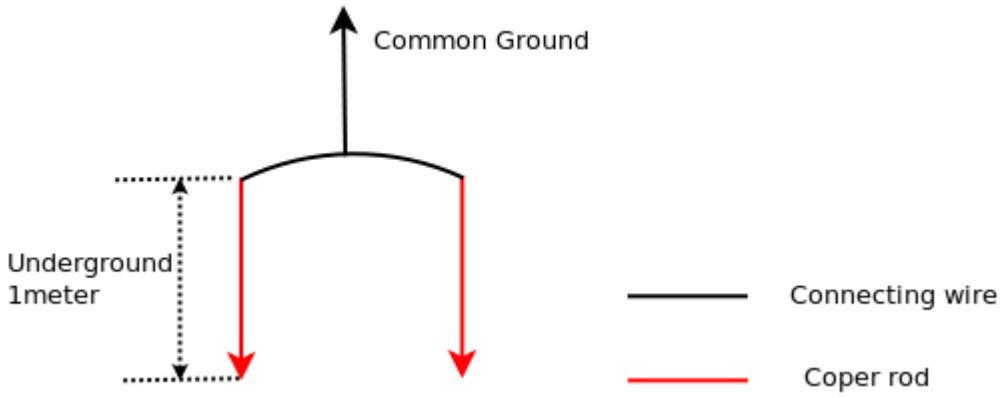


Figure-6 Buried underground copper

Lightning protection system should be provided with a heavy cable to interconnect the roof top terminals with the grounding system without any sharp bending.

5.4. Study result for Interviews

A number of interviews have been conducted with personnel's working at the district and health center level. The followings are some of the main challenges that the district healthcare facility facing:

- The health centers receive an average of 70-80 patients every day.
- Most of the employees who have access to internet use Google mail and yahoo for email service.
- Health centers send referrals to the district hospital with an average of two per day. Once a referral is sent, the health officers don't have a means to follow up the status of the referral they sent to district hospital. Knowing the status could have helped them to treat patients of the same case.
- The district hospital has a busy schedule to drive and check the status of the thirteen health centers in a daily base. This introduces oil, man power and time expenses.
- Most of the healthcare services are handled manually.
- There is no way for medical doctors and health officers to update their knowledge to the latest available information. Knowledge sharing between medical doctors and health officers is not that common.
- There is no application in use to collect and mange drugs inventory and medical records. The only medical recording system found was for Rusumo, Nyarubuye, Murindi, and Kirehe health centers for HIV patients.

The above mentioned points and the outcomes of questionnaire data analyzed on the previous section revel that there is currently a high demand on both infrastructure and service side to facilitate e-health activities for the district. The infrastructure deployment helps to elevate those problems related to communication and availability of information whenever needed. On the application perspective, it was possible to see that there is a demand on applications which can help to follow up referrals, drug management systems and online consultation.

Result for Service Demand analysis for Kirehe district

The outcome of the site survey, interviews, and questionnaires reveals that the below mentioned service are primarily needed to facilitate the healthcare service for Kirehe district:

- **Telemedicine:** Kirehe district hospital use to send patients to Kigali for referrals due to lack of well-trained physicians. The physicians most often assigned to district hospitals are newly graduates and there is a need to send referrals to Kigali in some cases. Besides online medical consultation, telemedicine enables medical doctors arrange knowledge sharing programs with their partners. Telemedicine service becomes more visible since the referral hospitals located in Kigali are already equipped with the required equipments.

  The video conferencing system currently in use by Kigali referral hospitals is based on HDVC. High Definition Video Conferencing is an open source and free solution for remote consultations. It supports high definition video conferencing between multiple parties at a time. The full video conferencing system composed of a High definition client, microphone, high definition screen and camera. Since the software supports high fidelity video quality, it suits the most for medical purposes such as remote consultation and clinical health care to patients at a distance. It improves access to medical expertise that would often not be available locally in distant rural communities. It can also provide an interactive cooperation platform for knowledge sharing and/or problem solving between medical professionals who are far apart from each other. The goal of HDVC implementation is to help remote and hardly reachable places, with lack of professional healthcare workers to communicate with central health facilities and get assistance in real time.

- **Network Services**
  - **DNS:** DNS service is needed to provide name-ip address and vice versa resolution.
  - **DHCP:** DHCP service is needed to provide IP address for the local network.
  - **Authenticating users:** It has been shown that the district healthcare service need ICT based solution to facilitate its service. This can be accomplished through wireless or wired networking technologies. It is visible that wireless networking should be used to provide full coverage for the whole area. Wireless technologies needs to have incorporated with authentication means to allow only legitimate users to access the network. Even if there are a number of default AES authentication tools, radius based per user authentication is seems to be much preferable to add more security and packet tracing for accessing sensitive medical records.

- **Electronic Medical Recording (EMS):** Health centers use to send referrals to health centers. But there is no way for health centers to follow the status of the referral other than using paper based systems. At the district level, medical records are stored using papers. Medical recording system is believed to give a chance for doctors get the chance to follow up the medical history of their patient. Installing the application to the health centers and district hospitals to have a centralized medical recording system allows doctors to easily follow the referrals.

5.5. Drug management application and questionnaires

DMA (drug management application) is an application that runs both on tablet and regular PCs. The application helps health facilities to keep track of their drug inventory and order in an ease way. It is developed by the collaboration of CSD 2011 AGLARBRI team and Karolinska Institute using Tanzanian and Ugandan drug management system as a base. The application can be fed with the drug forms used in the districts and it enables to detect and raise notifications when drug stock levels are low or reached a certain threshold. It provides a solution to the cumbersome and slow task of filling-in paper forms to order new drugs or to keep the drug inventory. The aim of the application is to provide the health care facilities with a tool to enhance drug inventory using digital accounting of drug and drug orders.

The outcome of the analysis made reveals that the following points as main reasons for needing drug management application for the district:

- Stock inventory is done manually on stock cards and copied to Ms Excel which is found to be time taking and vulnerable to error.
- There is no way to know the commodities which are at risk of stock anytime. It would be better to have a system which sends email automatically to notify for a custom which is at risk of stock.
- Monthly consumption reports mainly for malaria, tuberculosis, ARV opportunistic infection, HIV rapid test kits are performed manually. This is found to be time taking and vulnerable to error.
- Drug and pharmaceutical commodities are ordered manual which introduces extra transportation and man power cost.

Drug Requisition procedures in Rwanda

The outcome of the questioner and informal interviews made to Kirehe district and Kigali referral hospital pharmacists shows that the drug distribution system is handled in Rwanda using the below mentioned procedure. The drug management application should allow this procedure to be followed electronically:

- Requisitions are prepared based on monthly consumption rate & morbidity locally by health centers and district hospitals.
- The requisitions from health centers and district hospitals are channeled to district pharmacies located at district.
- The district pharmacies take the requisitions to CAMERWA accompanied by consumption reports.
- CAMERWA prepares and send the commodities to district pharmacies.
- District hospitals and health centers collect pharmaceutical products from the district pharmacies.
- The recipient of the health dispensary enters the received products on stock cards
- Inventory is done on stock cards and then on Ms Excel.
- Referral hospitals (e.g. KFH, CHUB and CHUK) are supposed to collect the commodities from

CAMERWA directly.

The DMA application, which is developed based on a Tanzanian and Ugandan drug management system, is installed at Kirehe district hospital to collect feedback about the features of the application. Questionnaire-B attached on appendix-C is prepared for this purpose. The result of the feedback revels that there needs to be amendments to the existing application and the following points need to be incorporated:

- There is a request for the application to support a field to put extra information on a pack base. This includes information about expiry date.
- Alert notification before the pills become out of stock and/or before the expiration date for the pills reached. The alert notification helps the pharmacist to take major before a serious problem happens.
- Develop an interface which enables DMA administrators to create accounts for pharmacists on a district hospital base. Accordingly design a recording system which will generate a system log when pharmacists make prescriptions and update the inventory. This will help to track changes made to the inventory and who made the changes.
- The system could also issue a receipt for the patient/customer after the drugs have been paid for.
- Implement an interface to prepare a report for drug inventory and orders on daily/weakly/monthly or for a specified time base.
- Develop an interface for DMA administrators to create interface for health centers automatically.
- Ability to support epidemic based reporting.

5.6. Local regulation

RURA (Rwanda Utilities Regulatory Agency) has the mandate to regulate telecommunication sectors, enhance and deploy service in compliance with the most advanced technology and also ensures telecommunication infrastructures have no adverse impacts on the environment and people in Rwanda. Building telecommunication infrastructures like handheld devices, base stations, towers, masts, long distance fiber optic installations, wireless networks should be licensed and certified by RURA before usage. RURA was contacted a couple of time to discuss about the local regulation on usage of unlicensed ISM frequency range on the selected areas. RURA states unlicensed ISM frequency band of 2.4/5.8MHz should be used with a limited maximum power to mitigate possible interferences.[40] Beside the wireless regulations, RURA also has a regulation which blocks operators to put new tower/mast in 1km are of an existing tower by any operator unless existing sites are not of sufficient height to meet the applicable requirement[39]. This introduces contacting MTN operator which is main service provider for Kirehe district. MTN was contacted to check its willingness if AGLARBRI uses existing tower and masts whenever needed. MTN has agreed to host the wireless equipments but it will charge on monthly base depending on the weight and power usage of the equipments.

The regulatory role for Tanzania is handled by Tanzania Communications Regulatory Authority (TCRA). TCRA also promotes sharing of infrastructures between service providers including towers and masts even if a strict limitation that blocks operators to put new towers is not specified.[41]. Regarding wireless frequency bands to use, TCRA allows usage of unlicensed ISM frequency band of

2.4/5.8MHz range with maximum of 1watt.[42]

6. Discussion

Interview

More than 81.4 percent of the Rwandan population inhabits in rural areas[*section-introduction*]. This implies that development policies and strategies should mainly focus on empowering and supporting the daily life of those communities. The outcome of the interview shows that Kirehe district healthcare service facility does not have any built in service[*section-interview*] or infrastructure currently[*section-questionnaire-A*]. Due to the fact that health centers don't have experienced physicians, an average of 2 referrals used to be sent to district hospital from 70-80 patients received by health centers per day [*section-interview*]. These referrals are sent using health centers ambulances which introduce extra expense for the health centers. Furthermore, the referral system does not allow health center officials to trace what has happened to the referral they sent[*section-interview*]. There are cases that referrals sent to district hospitals send back to health centers when the district hospital believes that the patient has shown improvement. Even on this second case, district hospitals does not have any means to follow up the status of their patient[*section-interview*]. Beside the referral system, district hospitals have a busy schedule to drive and check on all health centers under its district on a daily base[*section-interview*]. This daily schedule is needed to collect reports from health centers and it would have been solved if there is a means to send reports electronically to the district office.

Physicians at any level of the district perform their task manually[*section-interview*]. Medical history of patients is stored on cards *[section-interview*]. Currently there is no application used at the district and health center level other than HIV reporting tool[*section-interview*]. HIV reporting tool is in use by district hospital and some of health centers to send HIV infected patient records to their partners using VSAT technology. This facility is a good sign that ICT based solution can improved the communication gap between those healthcare partners.

Tanzania is a neighboring country for Rwanda. Majority of the country's population is also located in rural areas. Wide range of efforts has been made to support those communities to break the circle of poverty the country had in area of health, transportation and education. For health care service, both countries, Rwanda and Tanzania, have the same challenge of having lack of well experienced physicians. Doctors normally work at the district level for both countries[*section-interview*]. This communication gap and lack of medical doctors at health centers and health posts can be mitigated by introducing ICT based solutions*[section-interview*][33]. HIV reporting system used at the Kirehe district and health centers is a good sign for this. On contrary, entrepreneurs don't seem to invest more on ICT projects based on rural areas due to lack of electricity, transportation and business profit issues.

The outcome of the result collected from Kirehe district interview*[interview-section*] and previous works on ICT4RD Tanzania[*section-interview*][33] reveals that ICT can be used to achieve the below mentioned goals:

- ICT can be used to share knowledge between experts and medical doctors
- ICT allows to elevate lack of medical doctors at the health centers and health posts. This is achieved by allowing medical doctors at the district level to communicate to physicians and nurses working at health centers and health posts through VoIP and telemedicine applications. This can go further to giving online consultation.

- ICT based applications can be installed to facilitate the communication between healthcare units. This can be used to elevate extra expenses introduced by district hospitals and health centers while making a daily visit. Furthermore, the applications allow district hospitals and health centers to electronically manage medical records.

Local regulations

From the first section of the discussion it is shown that ICT is important for empowering developing countries economy mainly for rural districts. This can be achieved through ICT for development program. New projects in ICT4D can benefit from similar project by reproducing the technologies which have already been used. This reproducibility can only be done considering a number of factors into consideration.

For reproducing infrastructure technologies used by ICT4D Tanzania to a Rwandan district, a number of factors should be considered. The first thing that needs to be checked is the regulatory difference between the two countries where the reproducibility check will be performed. From Rwandan perspective the regulator is RURA while from Tanzanian side TCRA (Tanzania Communications Regulatory Authority) handles the regulatory role[*section-local-regulations*]. Both RURA and TCRA allows usage of licensed and unlicensed frequency bands for commercial use. Despite unlicensed frequency range, licensed frequency range needs subscription before usage. Both regulators set the maximum power usage limitation for using ISM bands[*section-local-regulations*]. In this regard, RURA seems to have a strict limitation with maximum power of 17dBm while TCRA allows usage upto 30dBm. Regarding sharing of communication towers, both RURA and TCRA promotes sharing of infrastructures between service providers. RURA have set a strict limitation whereby service providers are not allowed to put new towers and masts whenever there is an existing infrastructure in 1km area unless existing tower does not met height requirement. On the other hand, TCRA does not set a strict limitation on sharing of infrastructure other than promoting service providers to share existing infrastructures. This shows that Rwanda has a strict regulatory policy compared to Tanzania. This is also a good indication that replicating technical solutions to a Rwandan district should be done with a great care to meet local regulations.

Reproducing ICT4RD Tanzania to a Rwandan district should consider this regulation difference between the two countries and amendments need to be done accordingly.

Infrastructure

ICT4RD Tanzania is built to provide affordable connectivity for rural regions of Tanzania. The design basically includes connectivity, power source, and lightning protection infrastructures.

Connectivity is provided by fiber-wireless (fiber-WiFi) solution[*section-study-result-of-ICT4RD*]. The connectivity is achieved in two steps; the first connection is made using a fiber connection crossing main cities. The second connection enables extending the fiber using the wireless link. This second link provides coverage to remote sectors where reachability by fiber wouldn't be possible due to technical challenges including geographical nature of the region and total project cost. The fiber link has a number of Point of Presences(POP) mainly on the big cities making a local broadband. POP is equipped with a bifrost router or a layer two switch, power system, and cabling besides the local network. The layer two switch connect the fiber network to an outdoor wireless customer premises equipment through an STP cable. The outdoor CPE at the POP provides connection to a far end CPE

client using a sector or Point-to-Point antenna. In line with the local regulations, the system uses 2.4/5.8MHz unlicensed frequency range with a maximum of 27dBm transmitting power[*section-local-regulations*]. As there is no rule which stops service providers from installing towers whenever found necessary, two towers are installed at Manyamanyama and Mugumu. Each of them are 30meters in height. Besides those towers, a number of masts are installed, each of 40feet in height, at the client CPE sites to mount the access points.

By taking the same technology from ICT4RD Tanzania a local broadband is designed at Kirehe district in Rwanda[*section-result-for-infrastructure-design: Kirehe-district*]. The system uses fiber-wireless technology for connectivity. Using the same method ICT4RD Tanzania uses, the fiber connection is used as a hub where wireless connection will use as an uplink. This connection is located at Kirehe district hospital which makes the Point of Presence. To provide a full connection to all of the fourteen health centers and also possible high schools and administrative offices, a wireless link is used. This technology works well for the same reason ICT4RD Tanzania whereby geographical and economic factors are main challenges. The district hospital needs to be equipped with bifrost router, power system, and cabling besides the local networking. Ethernet cable will connect the bifrost router to outdoor wireless equipment which allows the fiber link to be reachable to wireless CPEs of the network. On the health centers side, the signal from the nearby base station would be received through an outdoor CPE and UTP cable would be used to connect to the indoor local networking. The wireless system is using 2.4/5.8MHz unlicensed ISM frequency band as a spectrum. Even though there is a local regulation by RURA that blocks the usage of power above 17dBm, RURA has allowed to use upto 30dBm considering that the area is very rural and the probability that frequency interferences will happen is very less. On the other hand, it is found that it is a must to mount repeaters at existing service provider base stations. The lightning protection and power system of the repeater stations will also be maintained by the repeaters.

It has also been seen that the fiber-wifi solution proposed by ICT4RD Tanzania can also be used for Kirehe district[*section-result-for-infrastructure-design: Kirehe-district*]. Radio mobile analysis for the designed network validates that enough coverage and receiver sensitivity*[section-figure-3][section-table-3*] has been achieved for all district hospitals and health centers.

The discussion on connectivity between the two districts shows that a smooth technology transfer can be made by taking care of country base regulations into consideration. This is mainly elaborated with the necessity of installing towers. Despite the fact that it is allowed to install towers in Tanzania, this does not work when it comes to Rwanda. This is due to the fact that Rwandan service provides have an already installed mobile communication towers to all districts of Rwanda and RURA forces use of existing network infrastructure rather than installing new towers. Another factor that needs to be considered is the frequency spectrum and maximum power regulations of countries which have an impact on infrastructure design of rural regions.

Power

Only six out of fourteen healthcare units in Kirehe district are connected to electric power grid[*section-questionnaires*]. The rest are using solar energy as main source of power. In case the solar power went down due to malfunctioning, generator power will be in use. Even though the remaining six centers which already have an electric grid use solar as a backup power source, some of their solar system has already stopped working which lets them to relay on solar power as a backup power source. Kirehe district healthcare facility is one good example. Battery charging system is not currently well

maintained at Kirehe district healthcare facility. One way or the other, this usage of generator power source has introduced extra cost.

ICT infrastructure in Rwanda can benefit from power source options proposed by ICT4RD Tanzania[*section-study-results-for-ICT4RD-Tanzania*]. The solution is developed in collaboration with Royal institute of Technology (through a project called GreeNet).[43] The outcome of the project can benefit ICT4D Rwanda in two ways. The first one is by providing backup and storage solution that can be used whenever the primary electric power source is down. This allows the extra expense which would be introduced by using generator powers as a backup source of power. Secondly, the outcome can provide high efficient yet low power consuming networking equipments. This also have a huge benefit as it allows reducing the total power consumption. As eight out of fourteen of the health centers are relaying on solar power as a main source of power[*section-questionnaire*], power solutions proposed by ICT4RD Tanzania would perfectly benefit ICT infrastructure of Rwanda.

Lightning Protection

Two types of lightning protection system are proposed for ICT4RD Tanzania[*section-study-results-for-ICT4RD-Tanzania*]. The first design allows the lightning protection for the two towers installed at Manyamanyama and Mugumu. The lightning protection system is built using five 1.2meter pure copper cables buried which are further connected to top roof lightening rod through a thick copper cable[*section-study-results-for-ICT4RD-Tanzania*]. The second type of lighting protection system used by ICT4RD Tanzania is for client CPE equipment side where a single copper rod is buried to provide the intended protection.

As the towers for Rwanda are maintained by service providers in Rwanda[*section-local-regulations*], the first method of lightening protection system proposed by ICT4RD Tanzania is not visible for a Rwandan system. The second design can be used for a Rwandan district with a little bit modification. As none of the healthcare facilities in Rwanda have lighting protection system installed[*section-questionnaire*], the lighting system build should also consider possible protection for indoor network equipments in addition to outdoor wireless equipments. This could easily be achieved by mounting the lightening protection system on top of the roof than mounting it on a separate rod[*section-lightning-protection-design][section-study-results-for-ICT4RD-Tanzania*].

Even if there are situational differences between Rwanda and Tanzania which is introduced by regulatory differences, ICT based projects in Rwanda can benefit from ICT4RD Tanzania. One general fact about the two bordering countries is that both of them face lightning strikes more often. Mounting lighting protection system for outdoor equipment is paramount. New ICT for rural development programs can benefit more from similar projects of ICT4RD Tanzania to build and replicate the lighting protection systems proposed by considering simple modification that could happen due to local regulations and existing network infrastructures.

Service

Information and communication technology forms an important role to insure quality of healthcare for rural areas. ICT based solution are believed to fill the gap between lack of medical expertise and patients[*section-interviews*]. Discussion[*section-ICT-for-East-Africa*] made for rural district of Rwanda and Tanzania states that ICT based solutions are paramount to facilitate healthcare service for the districts. Analysis made for Kirehe district shows that there is no infrastructure and service currently installed for the district[*section-interview*]. The only existing application used by the district is HIV reporting system which allows them to send reports to their partners. This is performed through a VSAT links.

A number of application have been proposed by ICT4RD Tanzania including Telemedicine, webmail, local voice service, web and networking service are some of them[*section-study-results-for-ICT4RD-Tanzania*].

- **Telemedicine**: it is an application which allows to fill the gap between medical expertise and far end health centers professionals. The solution has been in use by Rwandan referral hospitals and ICT4RD Tanzania program[*section-study-results-for-ICT4RD-Tanzania*]. Beside this, telemedicine is one of the services proposed for Kirehe district[*section-service-demand-for-Kirehe-district*]. This revels that there is a high demand for telemedicine service for the rural districts of Tanzania and Rwanda. Kirehe referral hospitals are using High Definition Video Conferencing (HDVC) for telemedicine service and online consolation. To provide the required compatibility and usage with affordable price, Kirehe district hospital can also be equipped with the same video conferencing system as of ICT4RD Tanzania and Rwandan referral hospitals. As the application is open source based, the service can directly reproduced from ICT4RD Tanzania and used by rural districts in Rwanda without any modification.

- **Webmail application**: It is an application which allows users to send and receive messages electronically. ICT4RD Tanzania have built a webmail service to be used locally[*section-study-results-for-ICT4RD-Tanzania*]. In a situation where there is a very slow uplink internet connection as the one for ICT4RD Tanzania, it is relevant to build a local webmail service. On the other side, employees of Kirehe district are using google mail and yahoo for sending and receiving emails[*section-study-result-service-demand-for-Kirehe-district*]. Employees working at Kirehe district hospital and Kirehe health center use the fiber link and those working at health center levels use their own modem to surf Internet and send emails. From the data collected from Kirehe district service demand data, it is visible that there is currently no interest of building a local email service. As there is no local infrastructure and a lot of users currently using electronic communication, it is expected that there is no interest for such services. Whenever the local infrastructure is built, there might be an interest for such services to be used for the district by replicating the same open source based email technologies used by ICT4RD to the distract. This allows build a locally managed fast electronic messaging system between the district hospital and health centers without using Internet connection.

- **Local Voice System**: Local voice system allows users to send instant messages and make calls. ICT4RD Tanzania uses SIP Express Router (SER) for building voicing system for ICT4RD Tanzania program*[section-study-results-for-ICT4RD-Tanzania*]. The results obtained from the data collected from Kirehe district shows that there is currently a big problem facilitating the communication between district hospital and health centers[*section-interviews*]. This

communication gap can be mitigated to some existent by using those applications. It allows medical professionals at the health level to send instant massages and make calls to district hospital with no cost. This allows the district to make use of the build infrastructure to the maximum possible way. Beside this, it allows medical expertise working at the district level to give first level advice for medical professionals working at health center level through the application before health centers send referrals. The outcome of this method is that, first, medical professionals will get the chance to learn from medical doctors working at the district level. Beside this, it allows to reduce extra expanse, time, and human resource introduced for referrals which could have been resolved by professionals working at health center levels through the consultation of medical doctors. Kirehe district has a lot to benefit from ICT4RD Tanzania on this regard. As the solution is running on open source yet high performance, the application can be directly used by Kirehe district healthcare facility.

- **Network services:** A local broadband infrastructure needs to have atleast DHCP and DNS servers to work properly[*section-study-results-for-ICT4RD-Tanzania*] [*section-service-demand-for-Kirehe-district*]. DHCP server provides IP addresses for connected networked computers. On the other hand, DNS server allows the translation of IP addresses to names and vice versa. Some other extra service including web and radius server can also be installed. The web service allows installation of web based applications and makes them available on the net. On the other hand, user authentication provides a tool to check the legitimacy of users accessing a certain resource. ICT4RD Tanzania used the above mentioned applications. The services are based on an open source distributions. As those services are mandatory to build a local broadband, new ICT4RD projects also needs to have those network services installed.

Besides the above mentioned services, Electronic medical recording (EMS) has been an interest for Kirehe district [*section-study-result-interview][section-study-result-service-demand-for-Kirehe-district*]. The main reason for introducing such an application is to allow doctors and physicians to maintain medical records of patients digitally. Furthermore, the application allows medical doctor at the district level and physicians at health center level to easily follow the status of a referral. This give the chance for physicians who sent referral to district hospital to learn what the problem of the patient was and how the treatment have been given by accessing the medical history. This can only be achieved by building a centralized healthcare service maintained at the district hospital and allows health center physicians to get access and update information accordingly. There are also a number of applications in use by Rwandan health care facilities even if most of them are at their initial stage [*section-Rwandan-health-care-facilities*]. This is a good indication that similar ICT4RD project can also take advantage of those services to facilitate healthcare services.

Drug Management Application (DMA): Drug management at Kirehe district is currently handled manually using stock cards[*section-drug-management-application-and-questionnaire*]. Due to a number of reasons[*section-drug-management-application-and-questionnaire*], drug management application was found to be one of the services that need to be provided for rural healthcare service. Currently, there is DMA application developed based on Ugandan and Tanzanian drug management system. The developed application allows healthcare units to order drug online and update their inventory accordingly. The data collected[*section-DMA-requisition-procedures-in-Rwanda*] shows that the drug management system in Rwanda is a two way process whereby healthcare units first make the order to the district pharmacy which will further send the request further to CAMARWA. It is clear that there is a work flow difference between the drug

management system in Rwanda and Tanzania. Application developed to digitalize those manually handled tasks should reflect those changes. That means, the application needs to atleast allow district pharmacies to accept drug order requests from district hospital, health centers, and health posts and a second interface to make an order to CAMARWA. At the same time the application should allow the district pharmacy to update their inventory automatically after making orders.

The result collected from the questionnaires after installing the DMA application locally at the district hospital[*section-DMA-results-questionnaire*] shows that the application needs more modification to fulfill the requirement of Rwandan drug management system. There is also a requirement that the Rwandan government wants to achieve. The requirement is to integrate healthcare services[*section-e-health-service-Rwanda*] together to build a centralized system. This does not mean building a single application which provides all the features but it means that changes made in one of the applications should be reflected on another application.

Due to the above mentioned explanation, it is not generally visible to directly reproduce the DMA application proposed by ICT4RD Tanzania and use it for drug management system in Rwanda. The application needs to undergo through modification to fit the Rwandan drug management system.

7. Conclusions

Millennium development goals aim to achieve the world into a living standard where everyone passed the poverty line. It has been a challenge for enterprisers of developing countries to cope up with competitive market and stand by their own. ICT is believed to be main driving force to achieve the MDGs in all sectors through e-health, e-learning, and e-education applications.

New ICT for development programs could benefit from previous similar projects by replicating obtained technical solutions to some extent. Intensive studies have been made to check how much those reproducibility of technical solutions can be maintained. The study also address what factors should be enabled to make a smooth technology replication. The reproducibility check is performed for both infrastructure and services. Generally speaking, the thesis concludes that, reproducibility of technologies is not possible unless country based factors are taken into consideration.

Infrastructure replication has shown positive result to some extent. The factors that need to be enabled are mainly related to local regulations. One good example to local regulations is frequency spectrum. Countries like Rwanda have a strict regulation that maximum power need not leave a certain level. There are also some rules related to telecommunication infrastructure usage mainly for tower sharing. Rwanda also has a strict policy that towers and masts should be shared by service provides whenever there is an existing tower in 1km area. Countries like Tanzania are a bit flexible and promote only sharing of towers whenever possible.

On the other hand, it is found that power requirement for rural district in Rwanda is similar Tanzania's rural districts. 57 percent of the health centers in Kirehe district of Rwanda are fully relaying on solar power. The district can benefit a lot from electric power storage system used by ICT4RD Tanzania. There is also such aspect of power system that the distinct can benefit by making use of low power consumption networking equipments.

Currently, there is no application in use at Kirehe district. Most of healthcare services are handled manually. Intensive study has been done to analyze what applications are used by ICT4RD Tanzania program. Telemedicine, webmail, voice IP, and network services are some of the services currently in use by ICT4RD Tanzania. Telemedicine, voice IP, and network service are under the list of applications required to meet the service need of Kirehe district. Those applications can be replicated and used by Kirehe district. On the other hand, local webmail application couldn't be adapted to Kirehe district at this instant due to the user's trend.

Drug Management Application is also another application need for healthcare service in Rwanda. The application is developed using Rwandan and Tanzanian drug management system as a base. The application was not able to be used at its current situation due work flow difference between the two countries. Tanzania and Uganda have a drug management system where healthcare units order drugs directly to a central drug distribution center whereas Rwandan system introducing an intermediater where by all orders would be handled on a district level which will further be sent to the central distribution center. The developed application is expected to integrate this work flow different to be used for Rwanda drug management system. There are also a couple of new features asked to be integrated to the existing application for full feature support.

Generally speaking new ICT for development projects in East Africa and the AGLARBRI ring can benefit from ICT4RD Tanzania program. The benefit comes in all aspects including connectivity, power systems, and healthcare services. The thesis revels that direct technology replication is not sometime possible. There are country wise regulations and work flow difference that applications and network infrastructure designs should consider. On the first place, it is not actually possible to build a single application which work for all East African or members of the AGLARBRI project. If developing a single application which works for all countries is a requirement, the only way this could be possible is to integrate those country wise difference in the application as an option. This option allows to technically scale applications to a wider space. On the other hand, network connectivity couldn't be build using the same network principle to scale ICT4RD Tanzania to the whole of AGLARBRI network. It has been seen that rural district in Rwandan and Tanzania have almost the same infrastructure and power system needs. However, the network design needs to be change from country to country reflecting local regulatory differences. Those factors could be based on usage of frequency spectrum, maximum power usage, or installation of tower, as proved by this thesis paper.

8. Future works

The thesis primary takes Rwanda and Tanzania rural districts as a case. Even though there are a number of reasons that this thesis can be do generalization for the results obtained to be used for similar districts in the East Africa, it's recommended that further analysis and sample are taken to make a concrete conclusion. The assumption takes the socio-economic, cultural, and current situations of the two countries as a base to make the generalization for atleast bordering countries of the east Africa which are member of the East African Community. However, the thesis believes that, taking more samples would be useful to make a concrete generalization.

Infrastructure

Detailed analysis for Kirehe district infrastructure design has been performed basing ICT4RD Tanzania as a base. Network specification for the design is attached on appendix-1. The specifications are submitted to KIST procurement officer a while ago. Once the procurement process is finished, a local broadband infrastructure can be implemented using the design and configuration details submitted as an outcome of this thesis work. The paper is submitted separately for KIST and KTH as one of the goals of the thesis work.

Service

To build a functioning network infrastructure for the district, detailed configuration and server build analysis are made. Equipments needed for building those services specification is attached as an outcome of this thesis on the appendix. The outcome of the system analysis and configuration details are submitted to KIST to be used once the procurement of the equipments is accomplished.

Drug Management Application

The DMA application needs further development as recommended on this thesis to meet users requirement. Once the development is performed, a field test can be accomplished with the procedure discussed below.

Field test for DMA from Rwanda perspective

Field test can be accomplished on step by step base starting form Kirehe district. The DMA application server can be kept at Kirehe district hospital or district pharmacy located in Kirehe. Kirehe district hospital, Kirehe health center and the district pharmacy are located in a single compound in 200meters radius. The remaining health centers will be reachable through wireless backhaul links. This allows all facilities to connect to the server through Ethernet cables and/or wireless links. There needs to be three actors to have a functioning drug management system on a district level:

- The DMA administrator, the district pharmacy and the health centers. The DMA administrator will be in-charge of maintaining the DMA application, create/remove pharmacists accounts upon request, maintain system logs, upgrade the DMA application, take a backup of the system in a timely manner and assist users whenever needed.
- The district pharmacy will have the position to control and manage drug requisitions coming from district hospitals and health centers and sends the commodities to the dispensaries depending on the requisitions they sent. It is also in position to summarize the requisitions and

send it to CAMERWA including the monthly report. This means that the interface for the district pharmacy should enable it not only to receive the drug reports sent from health centers and district hospitals but also to send the report to CAMERWA.

- The health centers and health posts will need to have an interface to generate and send consumption report on a specified time frame, send requisition to the district pharmacy, inventory stock management, and pharmacist based login interface.

9. References

[1] National Institute of Statistics of Rwanda, http://statistics.gov.rw/about-us/news/how-many-are-we-rwanda, access date 21/08/2012

[2] VISION 2020 Rwanda,http://www.gesci.org/assets/files/Rwanda_Vision_2020.pdf, April 2012.

[3] John Giles, (2009):what is ICT? http://www.michalsons.co.za/what-is-ict/2525, access date 21/08/2012

[4] Jagger A.K. and LokmanA.H.(1999): Impact of ICT in Education. The Role of the teacher and teacher training. Paper Presented at the European Conference on Educational Research, Lahti, Finland, September 1999

[5] Vartan Gregorian, Conference paper "What higher education must do to address the gap in ICT proficiencies", White House, http://www.ets.org/Media/Tests/Information_and_Communication_Technology_Literacy/ICTwhitepaperfinal.pdf, access date 21/08/2012

[6] ICT regulation toolkit: http://www.ictregulationtoolkit.org/en/Section.3160.html, access date 22/08/2012

[7] United Nation Development Program(UNDP) Millennium Development Goals: http://www.undp.org/content/undp/en/home/mdgoverview.html, accessed date 22/08/2012

[8] Jimoh, The role of Information and Communication in Achievement of the Millennium Development Goals(MIGs), College of Education, Azare

[9] United Nation ICT Task force: http://www.music.us/education/U/UN-ICT-Task-Force.htm 24/08/2012

[10] NICI plan Rwanda, http://www.uneca.org/aisi/nici/country_profiles/rwanda/rwanpol.htm, access date April 2012

[11] Tanzania vision 2025, http://www.tanzania.go.tz/vision.htm#2.0 TANZANIA PAST VISIONS AND IMPEDIMENTS, access date April 2012

[12] World Bank (2002):Information and Communication Technologies, A World Bank Group Strategy, The World Bank Group, Washington D.C.

[13] Richard Heeks: The ICT4D 2.0 Mainifesto: Where Next for ICTs and International development, University of Manchester, UK http://www.oecd.org/ict/4d/43602651.pdf

[14] Mike Anamy, Niall Winters, Designing for Development: Understanding One Laptop Per Child in its Historical Context, Standford University/London Knowledge Lab, USA/UK http://ieeexplore.ieee.org.focus.lib.kth.se/stamp/stamp.jsp?tp=&arnumber=4937397

[15] International Telecommunication Union report: Measuring Village ICT in Sub-Saharan Africa, 2007 , http://www.itu.int/ITU- D/ict/statistics/material/Africa_Village_ICT_2007.pdf, access date 24/08/2012

[16] Mellineum Development Goals, Education aspects, http://www.undp.org/content/undp/en/home/mdgoverview/mdg_goals/mdg2/ , accessed date 21/08/24

[17] IEEE, Kurt Junshean P.Espinosa, Jaime D.L. Cario, Analysis of ICT integration in Basic Education and Lessons Learned: The Case of the Philippines, University of the Philippines Diliman, Philippines

[18] IEEE, Md. Mahbubur Rahman, S.A. Ahsan Rajon, An Effective Framework for implementing Electronic Governance in Developing Countries: Bangladesh Perspective, Banglasesh

[19] EHRcom, http://www.CENtc251.org , access date 21/08/2012

[20] OpenEHR, http://www.OpenEHR.org, access date 21/04/2012

[21] IEEE, M.Arguello, J.Des, R.Perez, M.J.Fernandez, H.Paniagua Electronic Health Records (EHRs) standards and the Semantic Edge: a case study of visualizing clinical information from EHRs, University of Manchester, UK
[22] IEEE, Asif Zafar Malik, Telemedicine Country Report-Pakistan, 2007, Holy Family Hospital Rawlpindi, Pakistan
[23] IEEE, Bruce Zamaere, Elis Kullberg, On the Design and Implementation of a Virtualized Residential Gateway, Royal Institute of Technology, Kista, Sweden
[24] CareNet Fall 2011, http://csd.xen.ssvl.kth.se/csdlive/content/carenet-2011-fall, access date 21/08/2012
[25] CareNet Autumn 2010, http://vm-199.xen.ssvl.kth.se/csdlive/content/carenet, access date 21/08/2012
[26] Lars L Gustafsson, Dan Kibuule, Victor Kyalo, Amos Nungu, Jasper Ogwal-okeng, Jan M Olsson, Björn Pehrson, Cecilia Stalsby-Lundborg, Göran Tomson, Winnie Tumwikirize, Bruce Zamaere, Community health portals in Africa-concept and application for drug therapy, http://scholar.googleusercontent.com/scholar?q=cache:E6Vx7KcjyswJ:scholar.google.com/+ict4rd+africa&hl=en&as_sdt=0,5, access date 21/08/2012
[27] AGLARBRI CSD Team, http://csd.xen.ssvl.kth.se/csdlive/content/aglarbri, access date 21/08/24
[28] Francis Matmbalya, Susanna Wolf, The Role of ICT for the performance of Smes in East Africa. Empirical Evidence from Kenya and Tanzania, 2001
[29] Tanzania vision 2025 http://www.tanzania.go.tz/vision.htm#4.0 DRIVING FORCES FOR THE REALIZATION OF THE VISION, April 2012
[30] ICT4D Tanzania official website, http://www.ict4rd.ne.tz/, April 2012
[31] Robert K. Yin, Case study research; Design and methods. Newbury Park, CA, Sage
[32] Elis Kullberg, Hannes Junnila, Enabling factors for medical ICT in Africa, Master thesis, Royal institute of Technolgoy, Stockholm, Sweden, July 2012
[33] Zachariah Isamuyo, Open access ICT infrastructure in Rural Tanzania, Master thesis, Royal Institute of Technology, Stockholm, Sweden, November 2006
[34] Rocket M ubnt wireless radio ,http://www.ubnt.com/downloads/datasheets/rocketmgps/Rocket_M_GPS_Datasheet.pdf, April 2012
[35] Ubnt outdoor sector antenna ,http://www.ubnt.com/basestation, April 2012
[36] Ubnt outdoor dish antenna, http://www.ubnt.com/rocketdish, April 2012
[37] ICT4RD Project, Bunda-Mugumu, technical documentation, 2009
[38] SIP Express Router, http://sip-router.org/, access date 21/8/2012
[39] Guidelines for sitting and sharing of telecommunication base stations infrastructures, http://www.rura.gov.rw/docs/GUIDELINES_FOR_SITING_AND_SHARING_OF_TELECOM_BTS_INFASTRUCTURE.pdf, RURA, Rwanda, June 2011
[40] Regulatory Guidelines for the use ISM ban, http://www.rura.gov.rw/publication/ISMbandguidelines.pdf, RURA, Rwanda
[41] Electromagnetic radiation from telecommunication and broadcasting equipment and health, http://www.tcra.go.tz/headlines/radiationPressReleaseEng.pdf, TCRA, Tanzania, access date 21/08/2012
[42] Open spectrum info for Tanzania, http://www.volny.cz/horvitz/os-info/tanzania.html, access date 21/08/2012
[43] Better Performance, Clean Energy, http://csd.xen.ssvl.kth.se/csdlive/sites/default/files/projects/Pilot_Implementation_Proposal.pdf , Communication System Design, KTH, Sweden, December 16, 2011

10. Appendix

Appendix-A

Technical Specifications

CPE (Backhaul)

Frequency Range	Unlicensed 5.1-5.8GHz ISM band with MIMO
Gain	Upto 34dBm with possible power adjustment levels
Polarization	Dual if possible
Interfaces	Wired Ethernet port for POE and Data plus RF connectors
RF modulation	OFDM/TDMA with atleast 2RF output per radio
Latency	< 3msec
Antenna	Panel or dish antenna type
Management	**Locally:** through RS-232 serial cable(if possible) **remote:** using telnet, ssh, webGUI, SSL, TFTP, SNMPv1,SNMPv2,SNMPv3
Security	AES 128bit, Radius based authentication
Operating mode	AP/Bridge(WDS)/Client/Repeater(Programmable)
Data rate	54mbps for 802.11a/b/g and upto 300mbps for 802.11n
Coverage	Upto 40km
Standards	802.11a/b/g/n
Wind loading	200mph
Lightning protection	Inbuilt arrestors
Power source	Power over Ethernet(POE)
Operating temperature	15 to 65

Base Station

Frequency Range	Unlicensed 5.1-5.8GHz ISM band with MIMO
Gain	Upto 34dBm with possible power adjustment levels
Polarization	Dual if possible
Interfaces	Wired Ethernet port for POE and Data plus RF connectors
RF modulation	OFDM/TDMA with atleast 2RF output per radio
Latency	< 3msec
Antenna	120^0 Sector antenna
Management	**Locally:** through RS-232 serial cable(if possible) **remote:** using telnet, ssh, webGUI, SSL, TFTP, SNMPv1,SNMPv2,SNMPv3
Security	AES 128bit, Radius based authentication
Operating mode	AP/Bridge(WDS)/Client/Repeater(Programmable)
Data rate	54mbps for 802.11a/b/g and upto 300mbps for 802.11n
Coverage	Upto 40km
Standards	802.11a/b/g/n
Wind loading	200mph
Lightning protection	Inbuilt arrestors
Power source	Power over Ethernet(POE)
Operating temperature	15 to 65

Server

Power supply	Multiple(Minimum two)
Cooling fan	Multiple(Minimum four)
Processor	Multiple(Minimum two)
Memory	12G(or 6X2GB)
Memory type	DDR3-1333MHz
Memory slots	18 DIMMS
RAID disk array system	RAID 5
CPU Speed	2.9GHz
CPU type	Xeon -4 to 6 core
Processor Cache	8MB
Drive type	Hot 2.5 inch SAS (8 slots)
Drive speed	15K
Network Card	Gigabit network card minimum four
Expansion slot	PCI minimum four
Storage	2T minimum
Form Factor	Rack 42U

Quantity list

Item name		**Quantity**
CPE	Radio	11
	Dish antenna	12
Base Station	Radio	5
	120^0 sectorial antenna	8
	Dish antenna	1
Layer 2 switch		3
Bifrost router		1
STP cable		1450meter
HDVC set		1
HP server		1

Appendix-B

Contact address for stakeholders

No	Stakeholder	Contact Person(Name/Phone Number/email)
1	Gahara HC	788752656
2	Gashongora HC	788450773
3	Musaza HC	783187905
4	Bukora HC	788639360
5	Rusumo HC	788669390
6	Nyabitare HC	788543449
7	Nyarubuye HC	788545918
8	Nasho HC	788567844
9	Kabuye HC	783328424
10	Murindi HC	788871196
11	Ntaruka HC	788555267
12	Kirehe HC	788351556
13	Mushikili	788554859
14	Kirehe DC	788446582

Appendix-C

Quaternary-A

Kirehe District Health Center

The African Great Lakes Rural Broadband Research Infrastructure (AGLARBRI) project is a plan to develop useful and functioning ICT networks through rural areas surrounding Lake Victoria in Africa. The intent of the project is to stimulate local communities to get involved in the development and deployment of ICT services in rural areas in this region where there is demand for such services, but no supply. Kirehe district and its 12 health centers are consider as prototypes by AGLARBRI project to build a sustainable network infrastructure between its health centers and possible services. Please fill and submit the underlining form for each of the health centers of Kirehe to support the project. Please send an email for any question regarding this form to: biniamgm@kth.se

* Required

District NameThe name of the district: Kirehe District

Name of the Health Center *

Distance from Kirehe District Hospital *Distance in KM

Power availability *

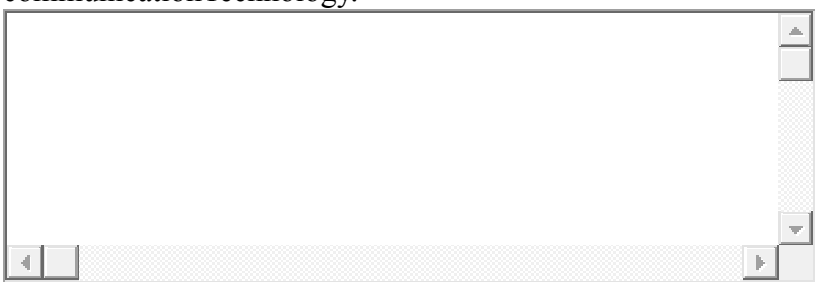
- Yes, Electric grid
- Yes, Solar energy
- Power Generator
- No power source

Internet Access *

- Yes, using fiber
- Yes, using wireless
- No
- Other:

Contact person for the health center with phone number *

Provide challenges that the health sector face which can be solved by the use of Information and communicationTechnology.



Provide any service that could benefit the health center?

Submit

Quaternary-B

AGLARBRI Drug Management Application

Drug Management Application (DMA) is developed by a team of students of KTH with the aim to provide health care facilities with a tool to enhance the drug inventory and drug orders. This page is developed to collect users input to improve the application in a more usable format. Any question regarding this form can be send to biniamgm@kth.se

* Required

Full Name
*

Address

Name of District *

District Hospital *

Email

Phone

Preferred contact method

Which features of the DMA application do you find more applicable for your district hospital?

Suggest new feature(s) that you think needs to be incorporated to the DMA application.

Submit