Bridging the Digital Divide in Africa: A Technology Perspective

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Abstract

In an attempt to qualify technologies that may assist bridge the digital divide, this paper examines the relationship between the digital divide and different current technologies as well as the up-to-date status of the digital gap in Africa using statistics provided by the International Telecommunication Unit (ITU). Looking at this imbalance of accessing information and communication technologies (ICTs) as a complex multi-faceted problem, we build upon different deployments in Africa to propose best technological practices that can assist in eradicating the challenge. These include networking technologies implemented in Tanzania, Malawi, and South Africa.

1 Introduction

An insight into how tremendous growth of ICTs has been attained over the past years has been provided in the recent "The World in 2010: ICT Facts and Figures". Internet usage has been presented to have sprung from under 500 million in the year 2000 to having now surpassed 2 billion mark of total users, as shown in figure 1.



[1]

Despite this growth, ITU figures indicate a dramatic broadband divide, with very few fixed broadband subscribers and mobile broadband subscriptions in Africa. In addition, while about 70% of the population in developed countries is online, only 21% of the population in developing countries is connected, as presented in figure 3.



However contrary to this, the recently improved ICT infrastructure investments in Africa reveal the vibrant commitment governments, private sector and international communities are putting in trying to address the digital gap. Additionally, this is evidently observed and stimulated by the opening of most African telecommunication markets to competition, coupled with the establishment of independent regulators in almost 90% [2] of the countries in the region. For instance mobile and broadband technologies are making major inroads in developing countries thereby by showing the abundant possibility for growth.

This paper attempts to qualify technologies that may aid in bridging the digital gap in Africa. Additionally, it also presents brief details of practical technological deployments in Africa to serve as models of best practices that can assist in eradicating the same challenge. These include networking technologies implemented in Tanzania, Malawi and South Africa.

The remainder of this paper is organized as follows. Section 2 presents the main ideas behind the digital divide in Africa and its relation to current networking technologies. Section 3 describes and discusses some successful deployments while our conclusions and directions for future work are presented in section 4.

2 The Digital Divide in Africa

A common vision of the digital divide is a multi-facet/multi-constrained problem aimed at reducing the technological gap subject to different constraints. These include social, cultural, technological, and political constraints. If expressed mathematically, such problem would appear as a complex NP-complete process requiring approximations to mimic an optimal solution. Such approximations involve networking technologies aimed at moving the Internet further to isolated regions using least cost optical, fixed and mobile wireless, and the emerging sensor technologies.

2.1 Optical Networking

Due to lack of legacy communication infrastructure, optical technology with its potential to provide large-capacity links using dense wavelengthdivision multiplexing (DWDM) is by far the most viable solution to greenfield deployment in Africa since the capital to be invested including cable laying costs may be similar to its counterpart, copper deployments. However, tough providing a theoretical capacity estimated to hundreds of Terabytes per second, Fiber might be harder to work with and termination equipment is still costly. Starting less than five years ago, the African Undersea Cable Map shown in figure 4 reflects a different picture from the ones depicted on different sites on the Internet revealing Africa as the "dark continent" with 1) the poorest luminosity during the night as a result of poor power grid infrastructure 2) the lowest numbers of google search and news hits and 3) the lowest scores in terms of digital performance. It reveals that the Terabytes of light capacity stored into the dozen cables landing on the African shores are signaling a new era in the numerical fracture. Motivated by the need to have terrestrial fiber connectivity complementing the major steps done on the submarine level, a Terrestrial optical network is being spearheaded by the Ubuntu-Net Alliance to cover the last mile of the optical network to improve connectivity in Africa. The efforts invested in such terrestrial connectivity are depicted by the terrestrial map in Figure 5.



Figure 4: African Submarine Undersea Map



Figure 5: African Terrestrial Fiber Map

2.2 Wireless Networking

Due to the mass production, hence less costly, the 802.11 standard has been proven as a mature technology for the last mile in developing world. However, in the past decade, Wi-FI has shown some limitations related to collocation with different other devices and interference in the crowded ISM free frequency band. A novel technology that addresses this issue and provides the potential to move wireless connectivity in Africa many steps ahead is the one introduced by the IEEE 802.22 standard for Wireless Regional Area Network (WRAN). WRAN uses some of the frequencies normally used for Television (TV) broadcast services referred to as "white spaces". With the recent migrations to digital TV transmissions, many of such frequencies have been freed and can now be adopted for data communications. The 802.22 standard harnesses cognitive radio (CR) techniques to enable the sharing of the broadcast communication band by having data communication being automatically routed to unused frequencies based on frequency auctioning and other frequency sharing techniques. Advantageously, since the TV communication band is in the lower part of the spectrum, WRAN link can span distances up to 100km, thereby making this a very promising technological option for many unconnected developing countries. Apart from

this, the standard provides broadband connectivity up to around 20 Mb/s for each access point installed. We believe that if economies of scale produce sufficiently affordable 802.22 based equipment; this will foster the outreach to many remote ICT unprivileged communities.

2.3 Mobile Networking

There is a high penetration rate of mobile phones in developing countries, especially in Africa as depicted in Figure 6, which are covering even the most remote areas. Consequently, by taking advantage of this, instead of only supporting voice, terrestrial links could be enhanced to support data capabilities, thereby extending ICT service connectivity to remote areas and at the same time bridging the digital divide.



Figure 6: ITU statistic on Mobile cellular subscriptions per 100 inhabitants, 2000-2010 [1]

2.4 Sensor Networking

In environment monitoring, wireless sensor networks provide the potential to bridge the visibility gap created by governmental weather, pollution and other environment monitoring stations and at the same time offer unprecedented and new abilities to bridge the scientific divide by enabling the observation and understanding of large-scale, real-world phenomena at a fine spatio-temporal resolution. They are based on an *"embedding-and-network"* paradigm where 1) sensor devices are embedded into the environment to capture its physical parameters 2) networked using radio signals to disseminate sensor readings

and 3) these readings are disseminated using different communication techniques to provide different services to different applications into a ubiquitous environment where information is accessed not only anytime and anywhere but also using anything and by anyone. When deployed in water resources management, they can be used to measure the rate, quantity, and direction of contaminant flow in water and the presence of different other water substances. WSNs can also be used to determine the rate of flow of a river and sometimes, using periodic samples at multiple locations along the river, the direction of the river flow. They can also be deployed in pollution monitoring activities using off-the-shelf gas sensors to measure the levels of pollutants in the air and thus protect the environment and human health. Emerging next generation sensor manufacturers are producing miniaturized weather stations which are hundred times much cheaper than professional weather stations while exhibiting the same features as professional stations. By changing the way we measure weather, these stations provide a high potential to improve agriculture and the fight against drought in many of the African countries where agriculture represents a big portion of a country economic income. However, despite these great opportunities provided by WSNs for the developing world, research and practice in field deployments are still in their infancy stage and only a few application deployments have been cited on wide spread practical deployment of WSNs in Africa.

2.5 Solar Powering

It can be envisaged that worldwide demand for electricity is expected to significantly increase over the next few coming years. In developing countries renewable energies, more especially solar energy, are promising solutions to meet needs for electricity in rural households and community centres in remote locations. Referring to typical real life lessons learned from Malawi, the country is considered to be one of the poorest countries in the world, ranked 153rd out of 169 countries, according to the United Nations Development Program (UNDP) Human Development Report of 2010, [3] and as such ICT services are confined to the main cities and towns, and are not readily accessible or fully utilized. It is estimated that nearly 80% of the population is reckoned to be living in the rural areas [4].

This evidently depicts a big socio-economic development gap between communities caused by the differences in the utilization and development of ICTs. Apart from very high electricity bills that pose as a challenge for rural people, the poorly developed electrical distribution network contributes to the digital gap as there are inadequate electrical power facilities to support ICT infrastructure in the rural areas. Statistics show that approximately 8% [5] of Malawi population has access to electricity, with less than 2% [6] from the

rural community. Efforts have been manifested by ICT service providers with greater focus being placed on the provision of rural communication services. In Uganda, one of the leading telecommunication and Internet service provider, Uganda Telecom Limited, introduced Coral - 200 solar powered mobile phones manufactured by ZTE which promises to revolutionise mobile phone usage especially among the country's rural populace with limited access to the national electricity grid [7].

Despite these kinds of efforts, the providers encounter the biggest challenge in serving the rural areas and villages as site access is often difficult and connection to electricity utility grid is seldom possible. [8]

Furthermore, due to high running costs and contribution to carbon emission, the adoption of diesel generators as electrical power source in Base transceiver stations (BTS) or telecom transmission tower stations is becoming unpopular. Consequently, many ICT service providers are embarking on solar powering solution projects. All the same most rural BTS sites still have back - up power arrangement using Diesel Generators for the main solar power as a provision in cases of extreme weather conditions. Still more due to high initial capital costs of solar projects, there is hesitation for service providers in adopting this powering option. However, the idea is found to be technically feasible and cost effective in long run.

On the other hand, in many parts of developing countries, as part of government and donor community initiative to boost ICT and combat poverty, Telecentres are being widely deployed with an aim of enabling the rural communities to be better informed on important issues which affect people's daily lives, businesses and any other social and cultural activities; through the use of Telephone, Fax, Internet, Radio, Television and other telecommunication media. However to fully achieve this, solar electric powering remains the basis through which information service infrastructures are built on [9][10] [11][12]. As described in this section, the use of solar powering is a possible strategy to be adopted in allowing isolated communities access ICT services.

3 Lessons learnt from successful deployments

Looking at the best technological practices that can fill the digital divide, this section presents some of the successful deployments in Africa that may be replicated to improve connectivity in Africa and reduce the infrastructural gap.

3.1 The Serengeti Network in Tanzania

The Serengeti network was deployed as part of the ICT for Rural Development (ICT4RD) program [13]. ICT4RD is a research and development project that was designed with a goal of creating a model for building and sustaining broadband communication networks in under-served areas. The approach is to create broadband Islands, defined as self-sustained local area networks that provide services in a local community with a capacity that is not limiting the spectrum of services. The Serengeti pilot is in the Mara region, northern Tanzania, connecting two districts of Serengeti and Bunda, with a total population of about 500,000 people [14].

Potential

In the 2005 Poverty and Human Development Report [15], Serengeti and Bunda districts were ranked among the poorest districts in the country, positioned at 116th and 119th respectively out of 119 districts. In 2006, a baseline study was carried out in Serengeti and Bunda districts to benchmark the needs of ICT [16]. The study revealed that agriculture and livestock are carried out by 90% of the population; both districts rely on the central government for about 95% of their budgets; and a few organizations both public and private have Internet via VSATs or dial-up, purchased using donor funds, usually via a project. The baseline study further noted that:

- Local government authorities require reliable communication both to the central government and to the citizens, thus broadband connectivity would improve their efficiency.
- The education sector has a shortage both of teachers and textbooks. The use of broadband connectivity would facilitate e-learning to compensate for the deficits and improve the quality of education offered.
- There was lack of trained staff in the healthcare sector, poor communication channels and insufficient facilities. Broadband connectivity could facilitate telemedicine where the few available medical doctors

could provide consultations to primary health centers via video conferences.

Thus, ICT4RD's primary focus was on facilitating basic public services, including education, health, local government and the local entrepreneurs, in order to progress the millennium development goals (MDGs).

Technology

On the communication link, ICT4RD model is about sharing of the passive infrastructure at cost-related basis. For the Serengeti pilot, a pair of fiber cable is provided by the power utility company in exchange for an Internet connection. The fibre was installed as underground wire in their rural electrification program. End users are connected through wireless technology using free spectrum, a mix of both 2.4 and 5GHz. A detailed description of the deployment is discussed in [17], the current network diagram is provided in Figure 7.



Serengeti Core Network

Figure 7: Serengeti Broadband Network.

Cost

To build Serengeti pilot as a self-sustained broadband island, the network operate its own servers, running the network services as well as user applications. On the back-end, the deployment included buying 2 servers, fibre termination equipments and wireless broadcasting antennas. Each connected institution was provided a computer, printer, UPS, Voice over IP (VoIP) phone, and WiFi (ubiquiti networks) antenna. Including labor, the fibre equipments and termination was about 10,000USD, setting up the wireless network cost about 10,000USD, the two servers cost about 5,000USD while connecting each institution cost about 2,5000USD. Once the network is up and running, connecting individuals who pay their own costs, buying the ubnt antennas is about 80USD (shipping included). A shared Internet is also provided at a cost of 25USD per each connected computer.

Impact

As reported in [18], the following highlights notable positive impacts associated with the introduction of this technology.

- 1. The local government use the VoIP phones and emails communications between departments as well as with connected schools and health facilities.
- 2. A pharmacy in Serengeti is reported using Internet to search for proper drug dose. Note that in Tanzania, it is not allowed but very common (especially in remote areas) for individuals to buy drugs from drug stores without a doctor's prescription.
- 3. A survey on Internet cafes indicated that frequent users are students and reporters. The students make applications to universities in the country as well as access registration or study results online. The reporters use Internet to send stories to their head offices in the capital city.
- 4. There is video on demand materials on the local servers for health and education sector. Furthermore, the project is still working with the responsible ministries to create a curriculum that will guide creation of local contents.

3.2 A Malaria Network in Malawi

An example of how low cost technologies can be used to bridge the Digital Divide is given by the long wireless network setup in Malawi. In 2008 a group of engineers from the International Centre for Theoretical Physics of Trieste (ICTP), Italy, in collaboration with local engineers, embarked in a project to connect a remote hospital to the Internet. A long wireless link was deployed in collaboration with the Malawi Polytechnic and the College of Medicine, to connect the faculty of Medicine in Blantyre to the hospital in Mangochi which was previously unconnected. The final goal was to allow medical staff

in Mangochi to communicate with their colleagues in the main hospital of Blantyre, where specialized doctors are available.



Figure 8: WiFi Network link Figure 9: Path profile from Zomba peak to Mangochi tower

A wireless link spanning the 160 km was installed using two hops: the first from Blantyre to Zomba (60 km) and the second one from Zomba to Mangochi (100 km). Zomba Peak was used due to its height of almost 2000 m above sea level. Deploying such long links presents technical and logistical issues. The technical ones have to do with the antenna pointing that at such distances is a very delicate matter. The logistical ones have to do with moving more than 300 kg of equipment around the country and with getting the approval of the telecom operators to use their commercial towers. Another aspect to be considered is human capacity building: for the link to be maintained after the installation, a team of highly skilled engineers had to be trained. ICTP considered this as a priority, and several training activities have been organized for Malawian engineers. Since the initial planning, two requirements have been considered as mandatory: the link had to provide a broadband connection and the equipment had to be low cost. Broadband was considered so important to allow future, unpredictable, uses of the network. The initial idea was to provide internet connectivity in Mangochi via the College of Medicine in Blantyre and to install video-chat software on the doctors' PCs. After a second visit in 2010, it was decided to install video IP phones and to connect smaller clinics around Mangochi to include them in a malaria database system. Bandwidth demand has thus grown in just one year, so the broadband request proved to be important. The low cost requirement had to do with the limited budget available but also to the sustainability of the network. If the network has to be locally maintained and expended, low cost was paramount. The new connections deployed in 2011 were possible because additional equipment was provided in 2009 due to its low cost.

A successful example of output of this project is the connection to St Martin's hospital. This is a remote clinic, in the Mangochi area, which did not have any internet connection. Bringing fiber to the clinic is out of discussion due to its remoteness and to the little economic value an operator would gain from the connection. A team of local engineers deployed a 10km wireless link and were able to connect the clinic to the main wireless backbone installed in 2009. The doctor at St Martin's hospital is now able to video-chat with his colleagues in Blantyre for consultation. Data on malaria cases are now electronically gathered on a weekly basis and transmitted to the Malawi ministry of health. Before the network was deployed, this was done manually with long delays.

3.3 Solar System in Malawi

Recently in Malawi, ICT services have seen an acute demand in renewable energy sector, for solar Photovoltaic (PV) performance data acquisition, monitoring and control of system operations; since the works are usually in rural inaccessible areas, while the technical supporting muscle is based in urban areas. Observation has indicated that the deficit of such services retards further development as it is challenging to successfully conclude on effectiveness, suitability and adaptability of installed plants in specific operating conditions. On top of that, the digital divide definitely contributes to the deficiency of such innovative projects as it is challenging for service providers to remotely manage ICT disadvantaged sites.

Conducted to serve as a model for eradicating this constraint, a research project aimed at developing a cost effective solar system monitoring application that continuously presents remote energy yields and performance measures to plant engineers was carried out. A test bed comprising of a solar PV power plant has been set up at Malavi Primary School and a central management system at Malawi Polytechnic. The project output gives direct access to generated electric power at the rural site through the use of wireless sensor boards and text message (SMS) transmissions over cellular network. Specifically, the application uses a Waspmote sensor board from

Libelium where two phidget sensors have been grafted to allow voltage and current readings. The proposed application combines built-in Waspmote SMS capabilities and the widely known FrontlineSMS software to achieve information dissemination from the PV system site to the monitoring site and also from this site to the PV system's supervisors. This is augmented by web publishing using PHP and associated graphing tools. A general view of the system is shown in Figure 10.



Figure 10: System Architecture: Solar PV system with wireless sensors and central management server

As a new innovative solution that demonstrates a low cost mechanism for the renewable energy sector using the existing mobile network infrastructure, the deployed application presents the following key benefits.

- Access to PV system performance from anywhere through the use of Internet.
- Reports of power output and energy production trends.
- Verification of system operation.
- Easy collection of data for service and maintenance planning.
- Use of open devices which lower the cost and enable the replication of the solution.

The choice of using the GSM network was dictated by lack of other transmission schemes in the Malavi area. On the other hand, according ITU report, The World in 2010, mobile and broadband technologies are making

major inroads in developing countries. Similarly, GSM networks cover most of Malawi and connectivity costs are limited given the competition of the two operators (AirTel and TNM). 2008 statistical data indicates that cellular coverage on land area of the country is about 86%. [19]

A number of experiments were conducted with the objective of monitoring the performance of the PV installation, for instance in terms of solar charging voltage and load voltage. Figures 11 and 12 show a graphical representation of these two parameters during a particular test period.



Figure 11: Solar charging voltage

Solar charging voltage had a constant trend as depicted in a snapshot of a two day period shown in Figure 11 and clearly follows a day/night pattern, as solar panels provide voltage during the day and provide little voltage during the night.



Apart from this, figure 12 shows a trend analysis of the load voltage that is essential in supplying power to the bulbs and AC sockets for the school block.



Figure 13: Load voltage (b)

For simplicity, referring to Figure 13, during the night the system obtains a constant voltage of about 12 V, which is supplied from the batteries. However due to activities that are running at the school during this period of investigation, the battery voltage is not sufficient enough to supply power throughout the period of little solar energy. Hence the dropping of load voltage and evidently observed power outage between 3 am and 10 am. This output indicates that the system was under designed and there is a need of adding one or more batteries to meet the required energy demands of the rural community school.

Impact

A brief presentation of results on solar charging and load voltages, serves as a tip of the iceberg on the accuracy of the remote monitoring application. In addition, the monitoring system has proved to lower management cost as timely information reaches the group at the Polytechnic right in front of their work stations. This assists in alerting the technical team of remote circumstances and also eases system study time for the researchers. On the other hand, the use of GSM communication allows for easy system replication to other remote rural renewable plants.



3.4 Pollution Monitoring in Cape Town

Figure 14: Cape Town Pollution Monitoring and Mapping

A sensor Test-bed using gas boards was designed and implemented in the city of Cape Town to measure the levels of pollutants using the WaspNet platform depicted by Figure 14 in two modes: (1) ZigBee mode where the sensor readings were stored on the SD card and later dumped on the gateway using ZigBee communication and (2) GPRS mode where the sensor readings stored on the SD card were loaded to the Gateway using a GSM Telit modem connected to the gateway. In both modes, the information collected by a sensor board carried on a moving bus was opportunistically loaded on the gateway upon contact opportunity between either a ZigBee base station or a GSM modem. The sensor board carried on the moving bus included seven different gas sensors.

Using a cloud representation where redder clouds represent higher pollution reading at that point, we considered two types of clouds: those without circles representing the pollutant levels taken in Zigbee mode and the ones with circles within them which present the pollutant levels taken in GPRS mode. The readings were averaged at a particular point if multiple readings were taken at that geographic location and the time label considered was the one of the last reading taken at that point. This provided images that give an overview of the results by spotting general trends with regards to the sensors. Looking at the pollution map depicted by Figures 14, one should note that

the sensor responds to the levels of the whole group of gases, and so is a composite value of the various gas concentrations present. While this doesn't allow for accurate measurement of the level of a particular gas, it does give an effective "neighborhood" which the various gas levels fall within, and thus an indication of the level of air pollution. Using the pollution map depicted by Figure 15, one can see that the Northern Suburbs of Cape Town which is more "polluted" than the Southern Suburbs, especially given the presence of an oil refinery in the area.

4 Conclusion and Future Work

This paper reflects on the impact of ICTs on the Digital Divide in Africa and building upon successful deployments on the African continent it further presents some guidelines on how the digital divide might be filled.

For the past decade, developing countries are confronting new additional challenges as a result of the globalization process and the emerging new information age. Without appropriate ICT policies and strategies, the developing countries risk worse socio - economic status that can be promoted by the digital divide.[42] It has been discussed that factors contributing to these challenges are largely related to high cost of both infrastructure and connectivity. There is great need for coordinated approaches together with skilled human resources across the sectors to allow efficient use of ICTs. Internet based information is dependent on electrical power; consequently lack of utility grid infrastructure in rural areas in many African countries makes it impossible to reach out to the communities. However, the paper suggests solar powering as the best powering option to eradicate this difficulty. In the same line, there exist technologies that can easily be adopted to fill the digital gap. Wireless Networking, Optical Networking, Mobile Networking and sensor networking are flavors of techniques that can assist in building ICT services to link up and support rural and information starved communities and institutions. This has been demonstrated with practical deployment examples in Tanzania, Malawi and South Africa that serve as best technological practices. For instance, experiments to evaluate the impact of daily climate variations and road traffic fluctuations on pollution, in South Africa, and broadband communication link supporting under - served areas in Tanzania are some of the success stories.

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