Sustainable Green Broadband Solutions for Bridging the Digital Divide in Africa

A Technical survey of feasible and affordable broadband solutions for rural Africa

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Abstract

The opportunities are ripe for green communications in Africa. In a consortium of academics and researchers from UK and African Universities, the authors of this paper diligently take advantage of the abundant sun, and natural African environment to present potential, practical and feasible green solutions to enable rural communications in Africa. This will empower both urban and rural communities to access affordable broadband services and applications. This research contributes significantly to bridging the 'digital divide' while reducing the carbon footprint (CO_2 emissions) by the communications sector as a whole. Through appropriate understanding of state of the art broadband access technologies, energy requirements, carbon footprint, current demand and projected growth in the target areas, this research establishes a match for these requirements. Studies reveal the ability of the maturing solar power technology to meet this need and demand. Further still, this research compares power consumption of current broadband access network technologies. It is based on a chosen network model to estimate power consumption using published specifications of representative commercial equipment. This enables us to design off-the-shelf affordable broadband access solutions to address this gap. One further great challenge to be addressed by this research is enabling communication infrastructural presence in communities without electricity, which is a common phenomenon in Sub Saharan Africa.

Keywords—Green Communications solutions;; Solar Power; Broadband Access; Sub Saharan Africa; CO_2 emissions.

I. Introduction

The 21rst. Century heralded the development of gross inequalities in the socio-economic conditions of different communities depending on how much information is accessible to them. Globally, there is a rising concern over the so called 'digital divide' or the digital split, which is an alarming socio-economic concept referring to the differing amount of information between those who have access to the Internet and those who do not.[1][2].

There has been a lot of discussion on the potential of Information and Communications Technologies (ICT) to enable and enhance the social economic development of various communities. Studies have shown that the rate of ICT distribution is directly linked to the general level of social economic growth [3]. Recent findings have confirmed that ICT plays a vital role in advancing economic growth and reducing poverty. A survey of firms carried out in 56 developing countries found that firms that use ICT grow faster, invest more, and are more productive and profitable than those that do not[4][5].

The concept of information has made it almost mandatory that no country can develop without involving and focusing on regional and global development perspectives. ICT is one such area that leaves no country or community an island anymore. The world is now networked in such a way that international cooperation and collaboration have become key phrases in today's socio- economic development forums.

Globally, the ICT sector was estimated to have contributed up to 16% of GDP growth from 2002 to 2007 and the sector increased its share of GDP worldwide from 5.8 to 7.3%. The ICT sector's share of the global economy is predicted to jump further to 8.7% of GDP growth from 2007 to 2020[6].

It against this background that the authors of this paper consider it timely to 'think green' and 'think practical' with regard to bridging the digital divide in Africa. This research takes a survey of the state of the art and current broadband prevalence in Sub Saharan Africa the target area. It combines research expertise of experienced academics in solar technology from the region with academic and research expertise in broadband access technologies and power management techniques and use these to propose a feasible practical solution to this problem. In this approach, we compare power consumption of the various viable broadband access network technologies based on a chosen network model to estimate power consumption per user. The parameters used are taken from published specifications of representative commercial equipment. This will enable us to propose off-the-shelf, affordable and moreover green broadband access solutions to address this gap. This will contribute significantly to the lowering of the carbon footprint by ICTs in Africa as a whole. It will also contribute to keeping the comparatively low carbon Africa even greener and thus contribute to current global efforts to promote low carbon technologies and economies. Besides enabling communication infrastructural presence in communities that are not on the national grid, it will also address the prevalent dilemma of insufficient power in the region. Although some communities are connected to the national grid in this part of Africa, they are still faced with frequent power outages through ‘load shedding’, a phenomenon where areas or regions are time tabled to be switched on and off the grid in order to share the available insufficient power whether in the rural or urban areas. Therefore, the move to the technology that can enable solar harvesting with a view of feeding some of the power into the grid is a novel idea and a major contribution to be furthered by this research.

II. Broadband Prevalence in Rural Sub Saharan Africa

A survey of the current status of broadband prevalence in sub Saharan Africa reveals that this potential has not been tapped as yet. The need for broadband in Africa in general and Sub-Saharan Africa in particular is still self-evident. Globally, Africa ranks third on the record of least internet users by continent which gives Africa a penetration rate of just over 15% in a population of over 1Billion [6]. Fig. 1 gives a graphic view of current Internet users worldwide with Africa still having fewer than 200 Million people online.

Nigeria, Egypt, Morocco, Kenya and South Africa are some of the African countries said to have good broadband penetration yet even then the status of broadband in these countries such as South Africa are said to be ‘ truly pitiful’ moreover at slow speed and at uncompetitive access costs [7].

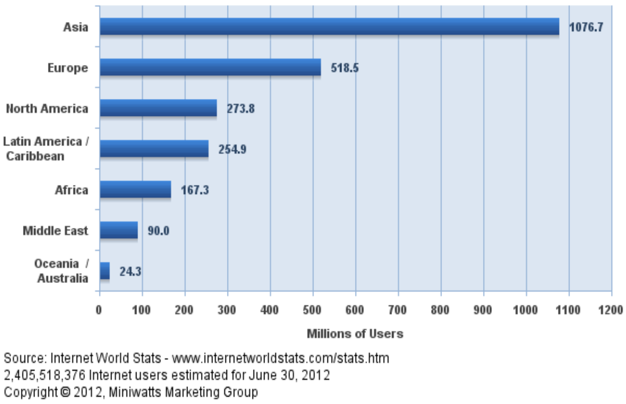

Fig. 1 Internet Users in the World By geographical Regions- 2012 Q2

Broadband access and prevalence even gets poorer when we narrow down to individual countries. Uganda for example whose recent developments have been so applauded in the Sub Saharan African region has under 5 Million people connected to the Internet in a population of over 30 Million as can be seen in Fig. 2.

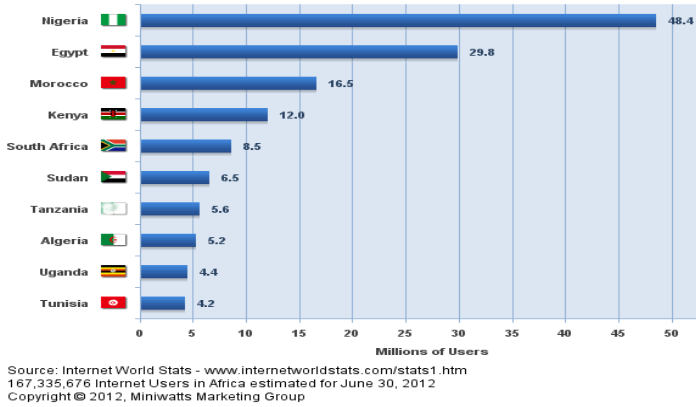

Fig. 2 Africa Top 10 Internet Countries 2012 Q2

III. Obstacles to Broadband Growth in Africa

Various obstacles have been identified by many researchers as hindering the quick growth of broadband access in the rural Sub Saharan African region in Particular. Principal among these is insufficient power [8]. Most of rural Africa is not connected on the grid. While other obstacles like high levels of illiteracy have been highlighted, these can be admitted only to an extent as proven by the prevalence of mobile phone communications for example. ICTs have been an impetus for ‘media literacy’ in their own right and use. People just use phones, game consoles, and play stations no matter what language they are programmed in. The same approach is potentially possible with broadband access facilities. Once the technology is made available; people will simply learn and use it.

IV. Solar Potential in Sub Saharan Africa

One of Africa’s natural endowments is an abundantly hot sunny climate. Seeing the sun up in the sky is almost a daily guarantee in most parts of Africa. As evident in figure 3, Africa is located in the prime spot for one of the world’s highest insolation regions with a solar potential of over 2000Kw/m^2/year. Currently the available solar harvesting technologies and uses include solar cookers, solar dryers for drying foodstuffs and photovoltaic (PVs) for electricity generation. The generated electricity is mainly used in low power consuming electric appliances like for lighting and charging phones. However, a major challenge in using PVs in Africa is the poor quality of the solar modules used in the PVs currently available on the market. There is therefore a perceived need for improvement in solar technology and utilizing the solar potential on a larger scale.

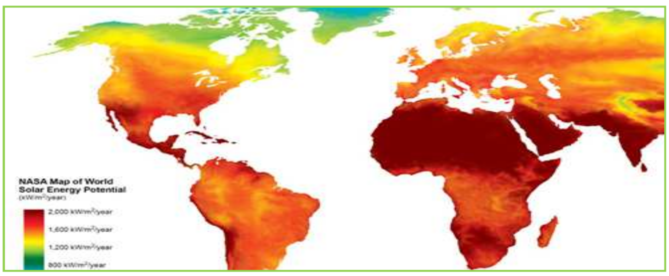

Fig. 3 Africa’s prime location for maximum insolation
Source: http://www.omsunpower.com/why_solar_energy.html

V. MATURE AND FEASIBLE LOW POWER AFFORDABLE BROADBAND ACCESS AND NETWORKING TECHNOLOGY

In the communications industry, energy consumption and efficient energy use is one of the main focus areas for research. Moreover, the access network is the largest energy consumer due to numerous active equipment at the customer premises [9]. Energy consumption in telecommunication and ICT depends on several factors e.g. the instantaneous network load, access technology, network architecture, Quality of Service (QoS) requirements, user's behaviour, profiles and mobility and traffic type and model. Factors we can control include the choice of energy efficient access and networking technology, equipment and feasibility of renewable energy sources. First, a comparison of energy consumption in the access networks based on different access technologies is given in Table 1.

Table 1 lists representative values of the parameters in Equation 1 for each of the access technologies considered here. The number of users per remote node and terminal unit for the two wireless technologies namely Worldwide Interoperability for Microwave Access (WiMAX) and Universal Mobile Telecommunications System (UMTS) correspond to the per-user capacities of 0.25 Mb/s. The number of users per remote node and terminal unit for the wired technologies; ADSL, HFC, PON FTTN and PtP all correspond to configurations where the ports on the remote node equipment(RN) and terminal (TU) unit are assumed to be fully occupied, in other words; operating at their known optimum capacity[10]. This informs our decision and choice of the most energy efficient technology for this survey. We then move on to demonstrate the feasibility of solar adequacy to meet energy needs for the chosen technology. Our earlier studies have detailed the use of solar for greener access networks[11][12].

VI. CHOICE OF NETWORKING TECHNOLOGY

This section outlines some options for a high-speed access networks and estimates their power consumption using published specifications of representative commercial equipment. This allows the comparison of the energy consumed by the different access technology options [9][10].

Several broadband access technologies are in use today. This research compares the seven briefly described below;

1. Asynchronous Digital Subscriber Line (ADSL). ADSL is a type of digital subscriber line technology, a data communications technology that enables faster data transmission over copper telephone lines than a conventional voice band modem can provide. It does this by utilizing frequencies that are not used by a voice telephone call [13].

2. Hybrid Fiber Coax (HFC), HFC is a telecommunications industry term used for a broadband network that combines optical fiber and coaxial cable. It has been commonly employed globally by cable television operators since the early 1990s [15].

3. Passive Optical Network (PON). In PON technology, a single fiber from the network node feeds one or more customers through a passive splitter [14]. An optical line terminal (OLT) is located at the central office, and serves a number of access modems or optical network units (ONUs) located at each customer premises. Each customer ONU in a cluster connects via a fiber to the splitter, and from there shares the same fiber connection to the OLT. ONUs communicate with the OLT in a time multiplexed manner, with the OLT assigning time slots to each ONU based on its relative demand.

4. Fiber-To-The-Node (FTTN). FTTN technology makes use of existing copper pairs [14]. Dedicated Fiber is provided from a network switch to a DSLAM in a street cabinet close to a cluster of customers, and high-speed copper pair cable technologies such as very-high-speed DSL (VDSL) or ADSL2+ are used for the final feed to the customer premises.

5. Point To Point (PtP); Provides high speed access using a dedicated Fiber between each customer premises and the network terminal unit in a PtP configuration. The customer premises employs an optical media converter (OMC) to convert between the electrical signals used inside the home and the optical signal used in the access network [14].

6. Worldwide Interoperability for Microwave Access (WiMAX). WiMAX is a high-speed wireless access technology. WiMAX was initially designed to provide fixed-point or nomadic wireless access services, but its design standards have since been amended to support full mobility. In our model, we focus on the use of WiMAX in a stationary setting, where each home uses an indoor modem to connect to a base station. The WiMAX base station is remotely located and uses fiber or point to point wireless backhauls to connect to the metropolitan and edge network.

7. Universal Mobile Telecommunications System (UMTS). UMTS is a cellular mobile system with high-speed broadband access capability. It includes radio access to a base station, and from there connects to the core networks for data and voice. This model usually adopts the most commonly used Wideband Code division multiplexing (W-CDMA) modification [14].

This parameters and power calculations are based on a network model[9][10] where we can compute power consumption per user (P_{user}) using equation (1);

$$P_{user} = \frac{1.5P_{TU}}{N_{TU}} + \frac{P_{RN}}{N_{RN}} + P_{CPE} \text{ where } A \leq A_{max} \quad (1)$$

Where P_{CPE}, P_{RN} and P_{TU} are the powers consumed by the customer premises equipment (i.e. the modem), the remote node and the terminal unit at the central office, respectively.

TABLE I. A COMPARISON OF THE FEATURES AND CAPACITIES OF DIFFERENT BROADBAND ACCESS TECHNOLOGIES

Access Tech	$P_{TU(KW)}$	N_{TU}	$P_{RN(W)}$	N_{RN}	$P_{CPE(w)}$	$P_{USER(W)}$	Technology Limit (A_{max})	Per User Capacity (A) Mb/s
ADSL	1.7	1008	N/A	N/A	5	7.53	15Mb/s	2
HFC	0.62	480	571	120	6.5	13.19	100Mb/S	0.3
PON	1.34	1024	0	32	5	6.96	2.4Gb/s	16
FTTN	0.47	1792	47	16	10	13.33	50Mb/s	2
PtP	0.47	110	N/A	N/A	4	10.4	1Gb/s	55
WiMAX	0.47	24400	1330	420	5	5.19	22Mb/s	0.25
UMTS	0.47	15300	1500	264	2	7.73	20Mb/s	0.25

N_{RN} and N_{TU} are the number of users or subscribers that share a remote node and the number of users that share a terminal unit, respectively. Note that the energy consumption of each access network can be split into three segments: the energy consumed in the customer premises equipment (P_{CPE}), the energy consumed at the remote node or base station (P_{RN}) by transceiver station, and at the terminal unit (P_{TU}) (which is located in the central office. The per user power consumption P_{user} is contributed by these three components, hence the expression in equation 1[9].

The parameter A is the average access rate in Mb/s and A_{MAX} the maximum access rate achievable by the access technology. The second term on the right hand side of (1) include a factor of 1.5 to account for additional overheads such as external power supplies and cooling requirements at the Central office[10]. The power per user equation links the consumed power in the network to the maximum capacity supported in the network. This is directly affected by the population density and distribution of the users within the geographic area.

From the values of P_{CPE}, in table 1, we can see that a proposal to deploy a hybrid Wireless-fiber Broadband access system that combines Passive Optical (PON) system to connect the metro and the cabinet with the Wireless Network technology to distribute the service to the customers at comparatively lower power consumption yet with reasonable access speeds is within reach (with trade-offs in power versus access capacity). PON and WiMAX networks seem the most energy-efficient access solutions at reasonably high access rates. Even then, this research focuses on using solar powered Wireless technology in the last mile. Indeed among several optical technologies, PON is one of the most promising high-capacity and low-cost optical access network technology. With the emerging bandwidth hungry applications and constant growth of internet subscriber numbers; the demand for PON is expected to grow rapidly [17].

In the long term; the proposed green broadband access solution is anticipated to provide access capacity in the range of the underlying wireless access technology capacities comparing and competing with current standards such as WiMAX or Long Term evolution Technology (LTE). WiMAX guarantees maximum downlink rate of 22Mbps while LTE reaches 50-100Mbps when supported with advanced antenna configurations such as Multiple Input Multiple Output (MIMO) technology.

VII. DISCUSSIONS

Hargittai and other studies have shown that the rate of IT diffusion is correlated to the general level of socio-economic development [17].

To be effective, efforts to bridge the digital divide need to focus also on the importance of international cooperation in ICT to bridge these digital divides at country, regional and global levels. This is absolutely essential to achieve an overall sustainable socio-economic development process[4].

Dabla has made a comprehensive literature review highlighting the relationship between ICTs and socio-economic development [3]. Jeremy Grace et al have also discussed and presented the characteristics and forces in ICTs which can play a pivotal role in the economic growth of a country in great detail [4][17]. Any meaningful development requires alignment with a country's development goals, buy-in and the involvement of local expertise. A collective ICT development vision for Africa exists and many governments are now developing national ICT policies[19].

Currently, we hold the view that ICTs should not be viewed as mere technology. ICTs are mediums of social change or vehicles to accomplish tasks. In [17], the developmental gaps in sub Saharan Africa are compounded by the problem of the digital divide. This is exacerbated not only by lack of access to ICTs but also by the challenges of inadequate pools of skilled persons [19]. Lack of access to electricity or unstable supply of electricity and lack of adequate technical support and the use, maintenance and rapid obsolescence of the ICTs due to continuous technological innovations and development[17]. Another side effect of insufficient power to enable broadband access in Sub Saharan Africa is the lack of power management tools to support the use of solar-powered communications system. Energy harvesting and storage from solar photovoltaics and energy management tools for monitoring the hybrid wireless-fiber broadband interfaces can be of great importance in improving availability and sustainability of power for Sub Saharan rural communities. Such challenges are being addressed through this collaborative research.

VIII. CONCLUSIONS AND FUTURE OUTLOOK

This research has presented a snapshot of the need for Broadband in rural Africa to bridge the digital divide. ICTs are viewed as the way to build new economic societies in this information age. ICTs are creating Economic opportunities for poor people and are amplifying their voices. It is no longer a matter of choice between ICT and health or ICT and education. Instead, ICT needs to be presented as the most effective medium available to enable the delivery of health, education, and even small business development services more efficiently. Our future work will focus on the energy-capacity considerations for the most energy efficient access technology and also will look into the user population density influence on these metrics. Further still, we will be considering the challenges of the Fibre-Wireless interface whose work is under progress by the Integrated Fiber & Wireless Technologies (TCFiWi) technical committee of the IEEE.

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