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Rural Healthcare Delivery in Sub-Saharan Africa:
An ICT-Driven Approach

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ABSTRACT

Access to quality healthcare is a major problem in Sub-Saharan Africa with a doctor-to-patient ratio as high as 1:50,000, which is far above the recommended ratio by the World Health Organization (WHO) which is 1:600. This has been aggravated by the lack of access to critical infrastructures such as the health care facilities, roads, electricity, and many other factors. Even if these infrastructures are provided, the number of medical practitioners to cater for the growing population of these countries is not sufficient. In this article, how information and communication technology (ICT) can be used to drive a sustainable health care delivery system through the introduction and promotion of Virtual Clinics and various health information systems such as mobile health and electronic health record systems into the healthcare industry in Sub-Saharan Africa is presented. Furthermore, the article suggests ways of attaining successful implementation of telemedicine applications /services and remote health care facilities in Africa.

KEYWORDS

Africa, HDI, Health, ICT, Tele-Health, Telemedicine, Virtual Clinics

INTRODUCTION

Developing countries are characterized with low Human Development Index (HDI) relative to developed countries. The HDI composition includes life expectancy at birth, education, and per capita income. Among the global ranking of the HDI within the developing nations, Sub-Saharan Africa has the least as over 60% of African population resides in the rural communities, characterized by poor infrastructure, low income, adversely scattered buildings, low literacy level, extreme poverty, higher level of inequality resulting from unequal access and so on (Adediran, Opadiji, Faruk, & Bello,

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2016). Sub Saharan Africa also lack access to quality healthcare services. In fact, nearly half of the World Health Organization (WHO) member states in developing countries (44%) have less than 1 doctor per 1000 patients, which is above the WHO recommended ratio of 1:600 (WHO, Global Health Observatory (GHO) Data, 2016). For example, the doctor-to-patient ratio in Malawi and Tanzania is 1:50,000, while in Liberia and Mozambique it is 1:35,000 (WHO, A health telematics policy in support of WHO's Health-For-All strategy for global health development: report of the WHO group consultation on health telematics, 1998). Therefore, even if these infrastructures are provided, the number of medical practitioners to cater for the growing population of these countries is not sufficient. However, the growing impacts of telemedicine have shown some positive effect in the healthcare delivery system, particularly for developing countries. This is because information and communication technology (ICT) can be used to drive a sustainable and veritable system through the introduction and promotion of telemedicine and integration of various health information systems such as the electronic/mobile health and electronic health record systems.

For successful implementation of these initiatives in sub-Saharan Africa, a low-cost platforms and systems are required. In addition to this, the applications used in accessing this service must be reliable and scalable. This is because of some of the peculiarities of this region such as large-scale poverty, among other factors. It would also require sustainable and competitive business models that would enable the private investors to key into the programme. Private sector investment is critical to the success of these platforms because most government in Sub-Saharan Africa lack the fund, expertise or willingness to drive this type of initiative. Furthermore, the success and likely take-up of such initiatives would require appropriate communication campaign for the end users for the adoption and promotion of virtual clinics and e-health system. This requires assessing the current knowledge base of rural dwellers about the virtual clinics services and e-health and also, to identify health-related problems that can be solved remotely.

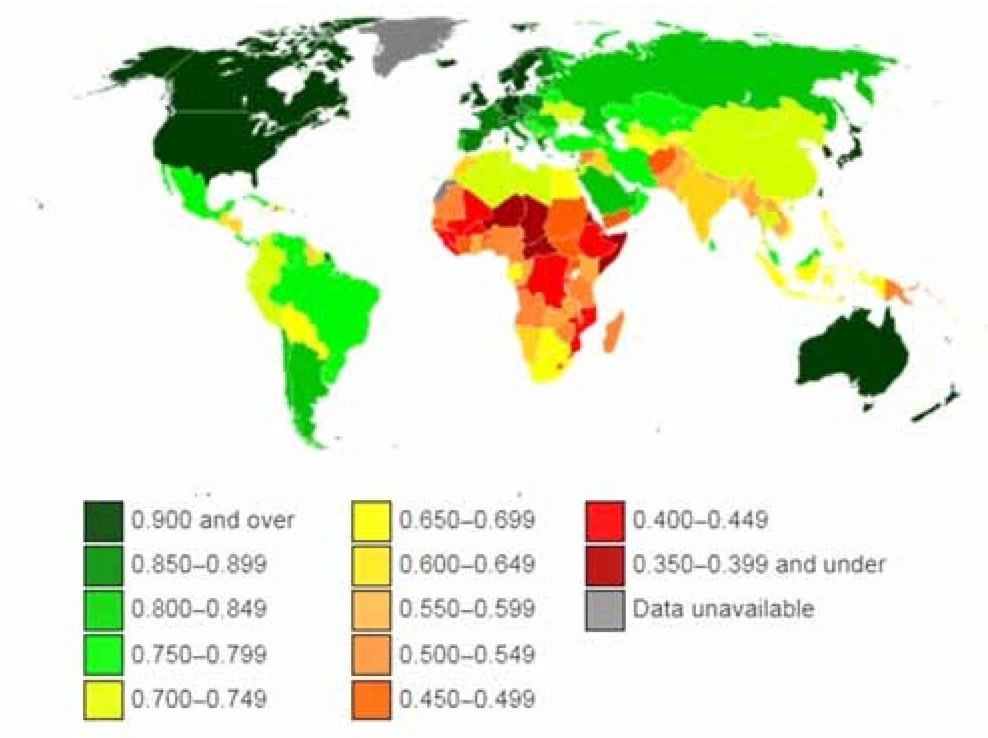
This article, therefore, aims to develop a framework for sustainable healthcare delivery (including health education) through development, implementation and promotion of ICT in the health care systems. Implementation framework, technical requirements for the development of virtual clinics, barriers to practice of telemedicine in developing countries, possible challenges that may be encountered during the implementation of virtual clinics in developing countries, some telemedicine case studies are all provided. Provisions are equally made for research directions and open issues for the successful implementation and integration of the ICT in the health care system.

OVERVIEW OF GLOBAL HUMAN DEVELOPMENT INDEX (HDI)

Human Development Index (HDI) is a statistical tool used to measure the overall achievement in a country's social and economic dimensions such as the health of people, their level of education and standard of living (Nations, 2016); (Bray, Jemal, Grey, Ferlay, & Forman, 2012). The main indicators are life expectancy for health, expected years of schooling as well as the actual years of schooling for education, and the Gross National Income (GNI) per capita for the standard of living (Kpolovie, Ewansiha, & Esara, 2017). A household with members sheltered in a well-furnished house; balanced diet food cooked using clean cooking fuel; with access to stable electricity; clean and portable water; private toilets would be rated high in terms of HDI index. Figure 1 shows the global HDI from the UNDP 2017 Report (Programme, 2017). This figure shows that Africa has the least HDI when compared to other regions.

According to the United Nations Development Project Report (Programme, 2017), Nigeria had an HDI of 0.527 in 2015 which is above the average of 0.497 for countries in the low human development group. The life expectancy at birth for Nigeria is the lowest at 53.1 when compared to Democratic Republic of Congo of 59.1, Ethiopia of 64.6 and even lower than the average for Sub-Saharan Africa of 58.9. The life expectancy value in terms of the Gender Development Index (GDI) had Nigeria having the lowest value at 53.4 and 52.7 for both the female and male respectively in

Figure 1. Human development index (Programme, 2017)



comparison to Congo which had 60.5 and 57.6, Ethiopia had 66.6 and 62.7 and Sub-Saharan Africa had 60.2 and 57.6, respectively. Life expectancy in years as a component and an indicator of HDI was calculated and fixed at 20 for minimum and 85 for maximum. National-level HDIs are created to reflect the priorities and problems relevant to the concerned country's level of development. However, the general trend shows Africa still has the least life expectancy as shown in Figure 2 (Santos, 2011).

Table 1 presents the population growth rate (%), birth rate (per 1000), infant mortality rate (per 1000), death rate (per 1000), life expectancy at birth (in years), % of GDP on Health (WHO recommends 5%) and GDP per capita (in US dollars), for three countries which are selected per region of the Africa continent making a total of fifteen countries. Malawi has more live births at a rate of 41 when compared to the birth rate of Libya which is 17.5 and the lowest among all the countries considered. More children under the age of one year died in Chad with an infant mortality rate of 85.4 while the country that recorded the fewest number of deaths among children under the age of one is Libya with an infant mortality rate of 10.8. Chad from the Central Africa has the highest number of death of 13.8 in a population of 1000 while the least death rate is recorded in the Northern Africa region with Libya recording just 3.6 deaths in a population of 1000 per year. Libya has the least population growth rate of 0.04% among the whole fifteen countries considered, while Chad has the highest rate of 3.31% according to the UN list. The lowest life expectancy of 50.2 means that Chad citizens may live up to the age of 50.2 year, while Morocco has the highest probability of living longer with a life expectancy of 76.9 years.

Only the Northern region conforms more to the 5% of GDP on Health recommended by WHO, with 5.6%, 5% and 5.9% for Egypt, Libya and Morocco respectively, while Gabon from the Central Africa having the least with 3.4%. The same Gabon, which surprisingly has the highest GDP per capital of $19300, while a ridiculous $900 is recorded for Liberia from the Western part of the continent.

Figure 2. Life expectancy list (Santos, 2011)

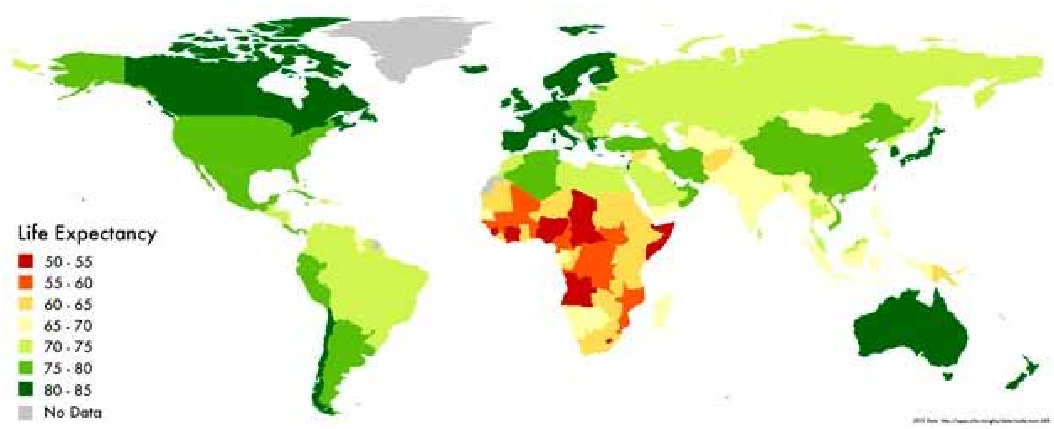


Table 1. Life expectancy list (Santos, 2011)

Factors/ Countries	Population Growth Rate% (2010 – 2015 List by the UN)	Birth Rate (per 1000)	Infant Mortality Rate (per 1000)	Death Rate (per 1000)	Life Expectancy at Birth (in Years)	% of GDP on Health (WHO Recommends 5%)	GDP per Capita (in USD)
World Standard	1.14	18.5	49.4	7.8	71.5	5	15800
Egypt	2.18	29.6	19	4.6	72.7	5.6	13000
Libya	0.04	17.5	10.8	3.6	76.5	5	9800
Morocco	1.37	17.7	21.9	4.9	76.9	5.9	8600
Ethiopia	2.53	36.5	49.6	7.7	62.2	4.9	2100
Tanzania	3.16	35.6	39.9	7.6	62.2	5.6	3300
Malawi	3.06	41	43.4	7.9	61.2	11.4	1200
Nigeria	2.67	36.9	69.8	12.4	53.4	3.7	5900
Liberia	2.58	38.3	52.2	7.6	59	10	900
Ghana	2.39	30.5	35.2	7	66.6	3.6	4600
Republic of the Congo	2.56	34.4	54.9	9.5	59.3	5.2	6700
Chad	3.31	35.6	85.4	13.8	50.2	3.6	2400
Gabon	2.25	34.2	44.1	13	52.1	3.4	19300
Botswana	1.99	22.1	29.6	9.6	54.5	5.4	18100
Namibia	2.28	27.3	35.1	7.9	63.6	8.9	11500
South Africa	1.08	20.2	31	9.4	63.1	8.8	13400

THE NEED FOR VIRTUAL CLINICS

There are a number of reasons for proposing the use of Virtual Clinics in Africa. According to the 2006 World Health Report, "Africa has 24% of the world's burden of disease but only 3% of health workers commanding less than 1% of world health expenditure (WHO, Global Health Observatory (GHO) Data, 2016). Furthermore, most countries in Africa are developing economies characterise by lack of basic infrastructure, poverty, increase in population and high ratio of doctor to patient. 60% of Africans lives in rural communities with grossly inadequate health care facilities. The inadequacy and sometimes lack of basic healthcare facility in some of the rural communities in Africa especially in Sub Sahara Africa has prevented specialised care in some communities. This made a lot of the rural communities to be more vulnerable to late discovery of ailment and access to basic healthcare system (Sood, 2002). Virtual Clinic offers a drastic solution to the gross inadequate access to healthcare delivery in Africa because it allows for medical examinations of patients while also allowing the provision of additional support from an off-site expert. This can help in earlier diagnosis and quicker care especially for diseases like cancer and diabetes. Virtual clinics would also provide a platform for educating the young medical personnel by the leading experts in health and medicine while also providing a platform for effectively facilitating research over a larger geographic area.

CONCEPTUALIZING VIRTUAL CLINICS

There have been lots of literatures that coined a word describing the use of ICT in medical diagnosis and treatment. In some literatures, *Telehealth* were used, while some *Telemedicine.* (Della, 2001); (Adebayo, Faruk, & Ayeni, 2013); (Strehle & Shabde, 2002). In this framework, Virtual Clinics are clinics without border, where remote patients can access medical practitioners; diagnosis can be undertaken remotely via the help of paramedics within the virtual clinics. Essentially, the virtual clinics will consist of building fully digitized with video conferencing facilities and basic telemedicine equipment. Some of these equipment are described in Indian's prototype which consist of solar powered tele-centres equipped with portable telemedicine workstations for recording electrocardiogram, blood pressure, heart beat rate (Pal, Mbarika, Datta, & McCoy, 2005). In advanced economy such as USA, virtual clinic models of mental health are under investigations (Beck, Manderscheid, & Buerhaus, 2018). This clearly show the commitment across the globe in this area. In the same way, recent study shows that the concept of virtual clinic is getting more acceptance among diabetic patients in the USA (Ahnood, Souriti, & Williams, 2018).

BENEFITS AND SERVICES OF VIRTUAL CLINICS

The following are some of the benefits provided by virtual clinics:

- **Provision of Clinical Supports:** Remote and real time direct patient care will be provided where health care professionals diagnose patients remotely through video conferencing with direct conversations. This helps to overcome the geographical barriers, connecting patients who are not in the same physical location with the health care professionals;
- **Clinical Data Transfer:** Sharing of compressed video, audio, medical data such as scanned X-ray, ultrasound and compressed images from one clinic to another;
- **Patient Monitoring:** Disease surveillance and patient monitoring are preventive measures. These help in providing useful information that are needed for early detection of epidemic outbreak and tactical actions for effective control;
- **Health Information, Education, and Specialist Referral:** Increasing use of digital technologies in health systems - online patient records keeping, clinical data digitalization and onward electronic

transmission, and appointment reminders by SMS - have not only reduced health resources and expenditure but have equally increased involvement of patients and lay personnel. Health education and specialist referral could be enhanced through virtual clinic implementation and integration.

TECHNICAL REQUIREMENTS FOR VIRTUAL CLINICS

The technical requirements for the virtual clinics would depend on the type of *telehealth* services to be provided. However, each clinic must satisfy the minimum requirements to provide the quality of services and guaranty availability. Some of these are summarized as:

- **Network Connectivity:** High Speed Broadband Internet is necessary; the network must have sufficient bandwidth to support real time delay intolerant applications such as audio. The network must be reliable and capable of providing services with minimal delay, jitter and packet losses. It must also support transmission of compressed video, audio and patient data. For optimum evaluation, a minimum of 768 kbps transmission speed is required (Adebayo, Faruk, & Ayeni, 2013) (Adebayo & Faruk, 2013; Adebayo et al., 2013). The connection between the health professional and the patient should appear seamlessly as if they are both in the same location. Wired broadband connectivity may not be feasible in most developing countries due to low penetration and neglects of the legacy wired backbone infrastructure, even though, it is the most reliable connection (Faruk, Adediran, & Ayeni, On the study of empirical path loss models for accurate prediction of TV signal for secondary users., 2013). Wireless communication systems can still provide the minimum data requirement. Although backhauling from fibre point of presence and/ wireless hub to far remote virtual clinics could be another bottleneck. But with the emergence of Software Define Radio (SDR) and Television White Spaces (TVWS) technologies (Faruk, Adediran, & Ayeni, On the study of empirical path loss models for accurate prediction of TV signal for secondary users., 2013) (Faruk, Surajdeen, Kolade, Ayeni, & Adediran, 2014), distant health outpost will be connected to the secondary and tertiary health centres. This backhaul network can be extended to provide point-to-point connections to the patient's home where web-based e-health patient services could be accessed. Both access and backhaul networks must be energy efficient. A hybrid approach may also be possible where distant clustered villages macro base station could be backhauled using long range Wi-Fi or point-to-point microwave units and each of the villages will have a small cell deployed within the umbrella coverage area of the macro BTS. This approach is called self-backhauling and has been found to be energy efficient when compared to the existing backhaul systems (Faruk, Ruttik, Mutafungwa, & Jäntti, 2016). In addition, there should be a reliable end-to-end connectivity networks between VCs;
- **Video Conferencing and Imaging Technology Facilities:** Video conferencing facilities are needed for real time communication between the health care professionals and the remote patients;
- **Health Information System (HIS):** HIS is a group of electronic medical records (EMR), electronic health records (EHR), and personal health records (PHC). The EHR provides patients health information; these include medical history, contact, hospitalizations and insurance information, family history, list of medications taken or currently prescribed, and allergies (Bello, Opadiji, Faruk, & Adediran, 2016);
- **Interoperability, Privacy, and Security:** The ICT infrastructures and facilities must be interoperable. The privacy and patient's confidentiality requirements as properly followed in the conventional hospital must be applied in this case with strict compliance. The video conferencing systems, data bases, work stations should be encrypted to provide adequate security for the patient records;
- **Reliable Power Supply:** The clinics must have access to reliable, clean and sustainable power supply at least during the consultations. Generally, there is power deficit in Africa and the dominant of the people without access are in rural and isolated areas which are characterised

with high rates of poverty, low income, lack of supporting infrastructure and extreme terrain features making it challenging to extend the electric grid. Furthermore, the market needs and lack of access to financial resources are also constraints. Although, ordinarily, the cost of supplying grid-based electricity to these locations, should be less when compared to alternative off-grid options, but, in most cases, the distances of these remote locations to the nearby transmission and distribution lines are beyond what could be sustained. Stand-alone microgrids could be viable option for nearby clusters of villages. Also, the clinics could be designed in such a way that the power consumption of the facilities is optimum and could be sustainably powered by solar power (Abdulkarim, & Abdelkader, 2017).

DATA RATES REQUIREMENTS AND END-TO-END VIRTUAL CLINICS CONNECTIVITY

Considering the feasibility of telemedicine, adoption and implementation would certainly depend on the available telecommunication infrastructure that would sustain the services. This will however, depend on how well the health care system is able to effectively exploit the capabilities of the ICT. Although the global strive to bridge the access gap is growing and this has been the giant strive of the Sustainable Development Goals (SDGs) (Griggs, et al., 2013) (However, universal access has not been achieved as there are still large percentages of the communities particularly in the developing countries that are currently underserved. Some technology options and universal models that would provide sustainable and cost-effective access opportunities in Africa were highlighted by (Faruk, 2017); (Bello, Faruk, & Segun, 2016) (Adediran et al., 2016; Bello et. al., 2016; Faruk et al., 2017). These models were based on the field campaigns undertaken in some rural communities in Nigeria. Table 2 illustrates a sample of some common basic and medical services and medical devices that are used in telemedicine and their data rate requirements.

In Figure 3, end-to-end connectivity for the virtual clinics is provided. Considering energy and backhaul costs issues in most Sub-Saharan Africa, the framework considers Energy Efficient (Green), TV White Space (TVWS) broadband connectivity Network infrastructure. The TVWS is the unused Ultra High Frequency (UHF) TV frequencies by TV license users. This is created as a result of the migration from analogue radio signals to digital TV radio frequencies. For example, most African

Figure 3. End-to-end virtual clinics connectivity

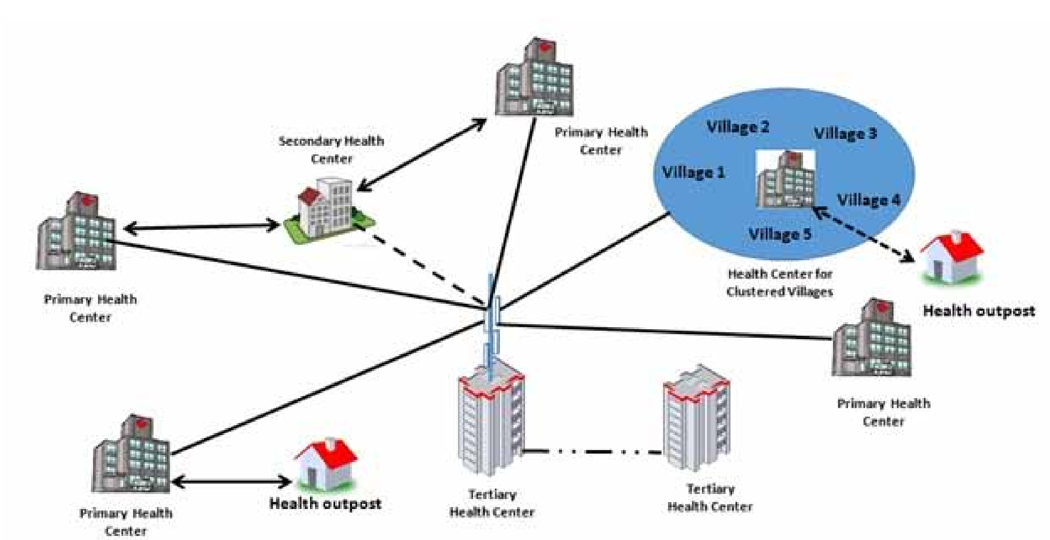


Table 2. Data rate requirement of common services and devices used by patients in telemedicine (Ackerman, Craft, Ferrante, Kratz, & Mandil, 2002)

Devices/Services	Data Rate Requirements	Feasible Technology Option	Comments
Real Time Audio Conversation	7.7 kbps-87.2 kbps	Wireless	This is VoIP call and depending on the codec type.
Real Time Video Conversation	768 kbps- 7 Mbps	Wireless	Depending on the resolution of the video
Digital Blood Pressure Monitor	>10 KB (data size)	Wireless	Depending on the resolution of the image
Digital Thermometer	<10 KB (data size)	Wireless	Depending on the resolution of the image
Magnetic Resonance Image	384 KB (Image size)	Wireless	Depending on the resolution of the image
Scanned x-ray	1.8 MB (size)	Wireless	Depending on the resolution of the image
Compressed and full motion video	384 kbps-1.544 Mbps	Wireless	Depending on the compression algorithm and size of the video

regions have huge unused UHF TV frequencies above 400 MHz. A TV White Space Device (WSD) is used to obtain TVWS frequencies as defined by the TV White Space Database (WSDB), so that it will not interfere with the TV frequencies used by licensed users. This WSD converts the unused TVWS spectrum, which can travel long distances and penetrate thick barriers, into broadband connections that can be provided freely to rural and remote areas where deploying fibre optic cables is quite difficult and/or expensive. In Figure 3, clusters of villages can be grouped and assigned to a single virtual clinic. These virtual clinics are referred to as primary health centres and have logical connections to the nearby secondary health centres that have physical infrastructures and medical personnel on ground. Critical and emergency cases could also be referred to the secondary centres. In a situation where the centres can't handle the cases, the patient can be referred to the tertiary health centres which are mainly located in the state capitals. The Virtual Clinics generally, intend to connect rural and/or remote areas with health services in the cities, improving access to medical personnel to enable remote diagnosis, prompt treatment and/or referral to the existing health facilities where prompt medical services could be given.

CHALLENGES OF VIRTUAL CLINICS IN DEVELOPING COUNTRIES

In real sense of it, telemedicine has the potential to deliver healthcare to rural areas of Africa. In general, it has the potential of eliminating a number of costs such as travel expenses, hospital bills, and patient transfer. However, certain challenges should be overcome in order to tap the full potential of telemedicine in Africa. This section discusses the challenges as follows:

- **Lack of International Framework:** In Africa efforts should be in place to enable medical personnel to deliver services outside their areas of jurisdictions;
- **Code Development:** Another area of concern is the development of codes that could only be recognized by the medical personnel such that international transfer of patient files would be a reality. This could be achieved with help of Skype, videoconferencing etc without breaching patient confidentiality. African countries can simply review and adopt what is obtainable in the USA, where the state medical board from different states developed a model that could ease license barriers between them, so as to allow the states access the facilities of telemedicine;

Table 3. Case studies

Reference	Project Name	Location/ Country	Services Offered	Tele-Facilities	Comments
(Weissman, Zellmer, Gill, & Wham, 2018)	Aurora Health Care, Department of Medicine	USA/ eastern Wisconsin	Genetic counselling	Genetics counsellors (GC)	The proposed model could be use by other institutions having shortage of clinical genetic professionals
(Torous & Hsin, 2018)	Digital therapeutic relationship	USA	Tool to harness, expand and potential of Digital healthcare	Smartphone application/ remote sensing technologies	Investigates the relationship between technologies and digital healthcare
(Alkmim, Marcolini, & Santos, 2013)	Telecardiology	State of Minas Gerais/ Brazil	Tele-monitoring to improve Heart Failure	Tele-echocardiography	Adoption of this techniques has shown reduction in cardiac related diseases despite the fact that about 2% of homes have fixed telephone line in Africa
(Wooton, 2008)	Dermatology	Botwana	Remote assistant and consultation to local dermatologist	Robotic telepathology	This technique shows a significant knowledge transfer between the consultant and the referring doctor
(Bhosai, Amza, & Beido, 2012)	Ophthamology	Ghana	Monitoring the effectiveness of eye	Retina Camera	This method reduces the transfer rate of eye patient by 80%.
(Mars, Ramlall, & Kaliski, 2012)	Psychiary	South Africa	Monitoring the mental state of an individual	Videoconferencing equipment and adequate bandwidth	This is used to reduce the time prisoner spent in jail awaiting the assessment of adjudicative
(Odedra, lawrie, Jensen, & Godman, 1993)	Internet based telephathology	Uganda	Internet based consultation for primary diagnosis and second opinion	Internet services with adequate bandwidth	This serves as motivation for health service provider and enhanced awareness
(Yunkap, 2018)	Physician consultation and referral	Senegal	Use of telemedicine technologies	Connection is by ISDN that allows transmission of medical images and other medical information	This reduces the problem of doctor-patient ratio

- **Economy Deficiency:** Economy is another problem facing the development of development of telemedicine in Africa and developing countries. The limited resource in these countries makes it difficult to have facilities in place that could facilitate the development of this technology. Some of the facilities include absence of technology, lack of Internet in the rural areas of the developing countries. However, rural and remote areas that need the applications of telemedicine remain largely unconnected;

- **Lack of Adequate Knowledge:** The knowledge on the role of technology is another factor militating against higher penetration of telemedicine in developing countries. This problem could be addressed by organizing seminars and conferences among the decision makers. Decision makers can always make their policies in developing countries for governments at all levels to provide the necessary supports in order to achieve higher penetrations of telemedicine. Also doctors and patients need more knowledge on the advantages, applications and potentials of telemedicine in developing countries;
- **Behaviour Change Communication:** The percentage of people in Africa that uses the web-based mHealth application designed to improve access to health information is still relatively low. The impact of this effort is largely limited by unavailability of accessible content in contextual local languages. At best, less than half of the digital content is made available only in few widely-spoken languages. In addition, usage statistics revealed a digital divide access are mostly limited to most digitally connected communities (Marine, Du Loû, & Méadel, 2015);
- **Service Delivery:** Referral network to facility will be challenging due to poor communication, lack of authority, absence of a formal referral system, and mistrust in public health care facilities (Leon, Schneider, & Daviaud, 2012). Also, lack training in record-keeping and counselling limits the reliability of data. Integration of mhealth such as decision support systems, SMS reminders and linking of health records will be challenging as the rollout will be limited to only areas with cellular network coverage.

From the foregoing discussions, there are many barriers to practice of telemedicine in developing countries. These barriers could be grouped into technological, organizational, human and economical. Also, the main barriers are the change in the model which healthcare providers are using in discharging their responsibilities. Others include health information and bureaucratic difficulties. More details on the outline issues are as presented in Table 4.

From the foregoing analysis of the problems of telemedicine in Africa, it can be observed that electricity could play a great role in solving these problems. Unfortunately, majority of the isolated areas are not connected to national grid due to poverty, low income, lack of infrastructure to mention just a few. These challenges make extension of the national grid difficult and make standalone renewable energy microgrid a viable option. Among these options, wind and solar energy are the most widely proposed renewable energy sources (Akinbami, 2001).

Recent statistics by the international energy agency has shown that renewable energy contribute 16 per cent of Africa`s electricity; as in Figure 4. Unfortunately, hydropower generation accounts for approximately 80% of the continent`s electricity generation as shown in Figure 5. These figures indicate how the isolated community are left behind the Scheme of things in electricity access; and make high penetration of telemedicine unrealistic.

However, the potential of solar energy microgrids are investigated. Proper sizing of the solar energy microgrid system is site specific and depends on many factors such as the availability of solar energy potential, the weather data, storage system, the load demand and other components (Abdulkarim, Abdelkader, & Morrow, 2017)- (Abdulkarim A., et al., 2018). In Figure 6 we provided the solar energy potentials of some African countries.

Recent analysis presented has shown that solar radiation averages 4.0−6.5 kWh/m^2/day and sunshine hours averages 1800−3000 h/annum (Sakaha, Diawuo, Katzenbach, & Gyamfi, 2017). Similarly, in Nigeria, this ranges from 3.5 KW/m/day to 7.0 kWh/m^2/day with 4-7.5 hours per day of sun light on the average (Akorede, O. Ibrahim, Amuda, Otuoze, & Olufeagba, 2017). In Liberia, monthly solar radiation rages from 4-6.5 kWh/m^2/day (Goanue, 2009). Most areas in South Africa received average solar radiation range between 4.5 to 6.5 kWh,/m^2/day and more than 2500 hours of shine per annum (Renewable Energy, 2018). Similarly, Namibia solar energy is among the best in the world with actual solar radiation average exceeding 6 kWh/m^2/day and 10 hours of shine hours

Table 4. Barriers to practice of telemedicine in developing countries

Indices	Comments
Poverty	Up till now, reasonable percentage (about 80%) of the populace live below poverty line
Communicable disease	Disease such as HIV, malaria, Tuberculosis (TB) and AIDS are still on the increase despite all efforts due to population growth
Maternal and child health	Mortality rate is still on the high side across the continent
Violence and conflict	The continent is categorised with continuous violence and conflicts
Workforce and shortage	Number of competent healthcare personnel remain unrealistically low
Critical mass	The continent is not able to build the required capacity
Poor district health information system	Both resources and staff are not adequate in the continent
Access	Lack of high speed and other communication facilities remain a challenge to telemedicine
Cost	High cost of communication equipment is serious setback to telemedicine penetration
Literacy	Education and technological advancements are still at infancy stages
Language	Language varies between healthcare providers and patient is a serious threat.
Political support	Lack of political will and unrealistic assumption contributes to low penetration of telemedicine
Electricity	Electricity supply is mostly un reliable, in adequate, unstable and not available sometimes

Figure 4. Renewables as share of total electricity generation (Quitzow, Roehrkasten, Jacobs, & Bayer, 2016)

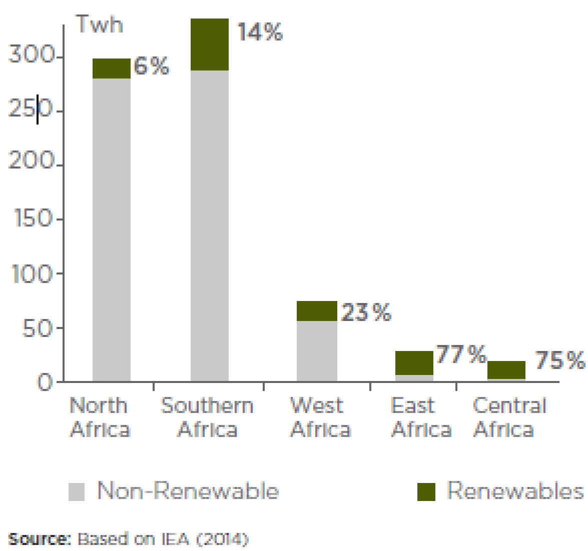
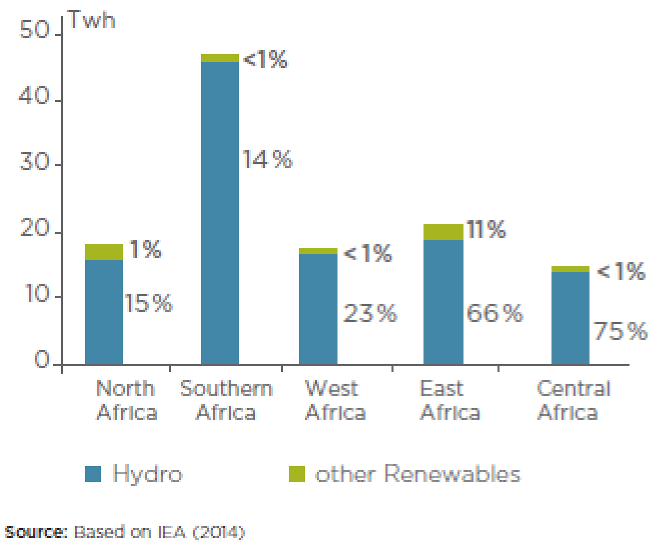


Figure 5. Share of hydropower and other renewables in renewable electricity generation in Africa (Quitzow, Roehrkasten, Jacobs, & Bayer, 2016)



for more than 300 days per annum (Renewable Energy, 2018). Boswana is enjoying about ~3200 hours of sunshine per year average total solar radiation is 21 MJ/m^2/day (Renewable Energy, 2018).

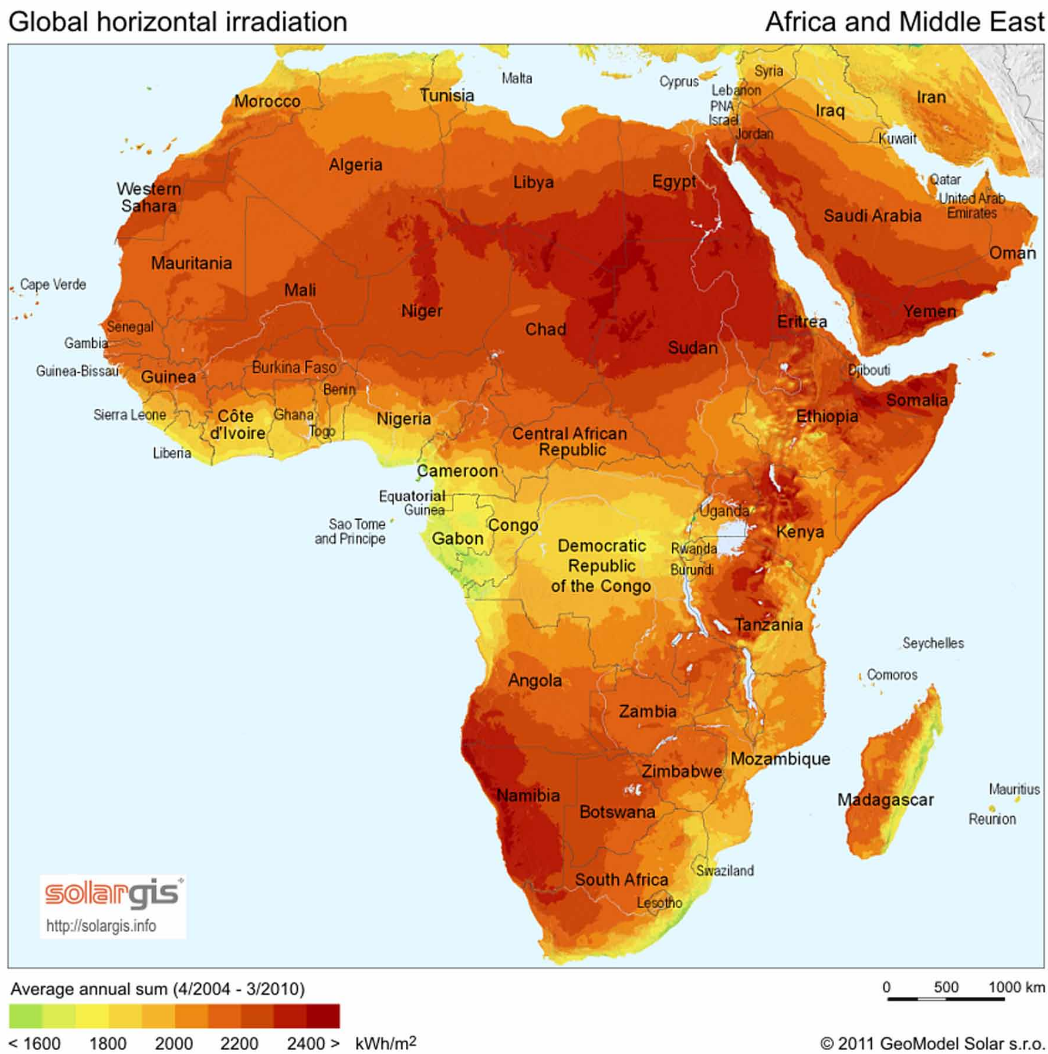
In east Africa Ethiopia has 5.58–6.66 kWh/m^2/day with average sunshine of 6 hours per day (Bogale & Alemayehu, 2012). Tanzania has similar potential of 4-6 kWh/m^2/day with an average of 8.5 sunlight per day (Hammar, 2011). Malawa is having similar figures of 4.20 to 5.83 kWh/m^2/day and average of 8.0 hours per of sunshine (Senganimalunje & Tenthani, 2015).

Similar investigation was carried out for Central Africa in which Congo has high isolation ranging from 3.25 and 6.0 kWh/m^2/day with 4-5 hours per day of sunshine hours per year (Kusakana, 2016). In similar passion Chad has between 3 and 8 kWh/m^2/day of solar radiation (Soulouknga, Coulibaly, Doka, & Kofane, 2017). Finally, Garbon has between 4 to 6 kWh/m^2/day with average sunshine hours of about 6 hours per day. General overview of the analysis presented has shown a great potential of Africa in solar energy. This is reasonable to claim that electricity problem could be resolve by using solar energy resources in the continent (Abdulkarim A., Abdelkader, Morrow, Falade, & Adediran, 2017).

IMPLEMENTATION FRAMEWORK

While the potential of ICTs to facilitate a better health service delivery has been emphasised in the literature, its implementation has not come without challenges in different environments. This has resulted into several implementation models/frameworks bearing in mind the peculiarity of services to be delivered and the exigencies of the location such services will be deployed. Achieving success with the initiation of telehealth service is not mainly hindered by the lack of availability of the appropriate technological tools in the market. Documented research abounds on the preponderance of tools and technologies that support telehealth (Park, 2006), (Puskin, Cohen, Ferguson, Krupinski, & Spaulding, 2010), (Chi & Demiris, 2015). These technologies support synchronous, store and forward, remote monitoring and mobile health/wellness telehealth solutions. Interventions capable of being delivered include consultation, education, social support, clinical care delivery, data collection and monitoring psychosocial/cognitive behavioural therapy among others (Shen & Naeim, 2017). In

Figure 6. Solar map of Africa (Solargis, 2018)



fact, Grady opined that advances in technology in the area of health care delivery have outpaced the rate at which such technologies are effectively integrated into heath care systems (Grady, 2014). One of such is the disruptive innovation capability fostered by telehealth technologies, with capacity to bring about improved outcomes in significant areas. Similarly, (Nagel, Pomerleau, & Penner, 2013) also reported modalities of telehealth and the rapid evolution of technologies outpacing empirical knowledge generation in support of nursing practice (Nagel, Pomerleau, & Penner, 2013).

Whereas researchers in (Schwamm, et al., 2017), concluded that the barriers impeding telehealth implementation can be organised into 3 distinct classes which are financial, technological, and legal/regulatory barriers (Van Dyk, 2014). The major concern has been that of implementation, which has elicited quite a number of attentions from the research community. A telehealth sustainability framework presented by (Isabalija, Mbarika, & Kituyi, 2013) focused on issues bothering on social, institutional and technological environment. The interplay of these with knowledge management and donor involvement is postulated to deliver a sustainable telehealth program (Isabalija, Mbarika,

& Kituyi, 2013). A further breakdown of these can be seen in a comprehensive review of telehealth implementation frameworks of (Van Dyk, 2014), identifying a number of themes to drive a successful implementation. These are: technology (availability, accessibility and competence in use); management of change and organizational behaviour; economics, finances and costs; policy, governance and legislation; organizational design and service design; society and community; technology use and acceptance; access and quality (Van Dyk, 2014).

Supriyanto (2011) identified standards and business models as key requirement to be given attention towards sustainable implementation (Supriyanto, 2011). Towards attaining a sustainable EHR in Nigeria, (Bello, Opadiji, Faruk, & Adediran, 2016) advocated for a bottom up implementation championed by technology enthusiasts with research funding and donor support (Bello, Faruk, O., & Segun, 2016). This is to be in conjunction with regulatory bodies, supported by government agencies and embraced by practitioners and health institutions.

This further buttress the importance of stakeholders in the implementation of e-health programmes. These stakeholders as identified by (Charles & Boxerman, 2003) include employers, the patients, care providers, government authority, insurers, researchers and educators (Charles & Boxerman, 2003). The different stakeholders play distinct roles in the implementation framework which is presented in Table 5.

Table 5. E-health stakeholders role (Charles & Boxerman, 2003)

Stakeholders	Activities/Role
Employers	These could be government or private concerns. They are interested in costs associated with providing the service
Patients	Their interest lies on the ease of information access which reduces the financial cost and time taken in travelling to health facilities
Care providers	They are saddled with the responsibility of timely and adequate information provisioning.
Government authority	Functions include standard regulation and uniformity of service. Implementations in public health facilities is also directly under the purview of the government
Insurers	Interested in acquiring information to be used for claims about a patient
Researchers	Focus on research opportunities to strategically position the health sector
Educators	The relevancy and adequacy of content delivered to practitioners etc

By implication, driving a successful implementation requires all stakeholders to play their role. This can only be ensured when there is a clearly outlined documentation to pursue the implementation. It also goes to say there is a need for coordination between the e-health stakeholders which has been identified by Rodrigues (Rodrigues, 2003).

A consolidated framework was provided by (Ross, 2016). This was based on the extraction from the literature, factors considered to be important for e-health successful implementation. They are: characteristics of the e-health innovation, outer and inner setting, individual characteristics and finally the processes involved. All these factors are multidimensional and could greatly enrich the implementation plan.

A proper articulation of the provisions of these frameworks can enhance the delivery of telehealth services and drive a successful implementation. However, a peculiar characteristic of the Nigerian rural community requires further attention in terms of connectivity and energy supply. While telecommunication penetration is improving in the country, the rural component of the improvement is near negligible. Similarly, the poor state of energy production requires special attention. With these in mind the End-to-end virtual clinics connectivity presented in Figure 3.

CONCLUSION AND RESEARCH DIRECTION/OPEN ISSUES

This paper has shown how Information and Communication Technology (ICT) can be used to drive a sustainable and veritable health care delivery system through the introduction and promotion of Virtual Clinics and integration of various health information systems such as Electronic/Mobile Health and Electronic Health Record systems into the healthcare industry in Sub- Saharan Africa. The paper provides a framework for sustainable healthcare delivery through development, implementation and promotion of energy efficient ICT in the health care systems. Furthermore, the paper identified that for a successful implementation of these initiatives in Sub- Saharan Africa, the private Sector investment is critical. This requires disruptive innovative and sustainable business models that would drive the investments.

The specific network requirements in terms of reliability, bandwidth and availability need to be assessed properly to guarantee quality services to patients. Research efforts are needed towards, gathering and analysis of the requirements necessary for electronic health record system development and coordinating policy support. A clear cut regulatory and legal framework for health policies is needed. This will include drafting the necessary legal documents for the incorporation especially the constitutions containing (Objectives of the patients, qualification of care givers, Duties of care givers, researchers, rights of patients, other ethical considerations like protection of personal health data, appointment of trustees etc).

For successful take-up, an appropriate communication campaign for the end users for adoption and promotion of virtual Clinics and e-health system is needed. This requires to assess the current knowledge base of rural dwellers about the Virtual Clinics services and e-health and to identify health-related problem that can be solved remotely. The paper recommends the use of other methods to explore the use of virtual clinics in Africa with help of questioner and other possible techniques available. This could assist in creating more awareness in the continent and among policy maker in the continent.

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