On Telemedicine Implementations in Ghana

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***Abstract*—Most Sub-Saharan Africa countries including Ghana experience a shortage of medical professionals, especially in the rural areas. This is mainly caused by the low-intake of students into medical schools due to inadequacy of facilities to train students. Also, a number of medical students graduate and emigrate to foreign countries to seek new opportunities and enhanced living standards. To reduce the effect of this, telemedicine is being implemented in certain areas to provide healthcare. Much as advances are being made in information and communication technologies, the advancement of telemedicine in developing countries still needs to upgraded and extended to cover more areas. Some categories of telemedicine have little to no implementation in Ghana due to lack of resources, little government support as well as the absence of structured frameworks and policies to ensure their implementation. This paper seeks to present telemedicine applications and implementations in Ghana till date as well as suggest some recommendations to mitigate some of the challenges impeding the advancement of telemedicine.**

***Keywords*—Telemedicine; Ghana; m-health; store-and-forward; information and communication technology**

I. Introduction

A substantial percentage of the population in most developing countries is not assured access to good quality healthcare, especially those in rural areas. The conventional primary healthcare in Ghana refers to primary healthcare through the Community-based Health Planning and Services (CHPS) compound, health post and health center. This usual mode of delivery is besieged by a number of challenges. Health facilities find it difficult to employ enough trained health professionals to manage the staggering number of people needing care due to limited budgetary allocation. According to the World Bank, rural dwellers constituted about 45% of the country's population in 2016 [1]. Unfortunately, this section of the populace is the worst affected in terms of the inequitable distribution of healthcare resources [2]. The Ghana Health Service in 2017 revealed that the average doctor and nurse to population ratio are one doctor to 8,431 and one nurse to 627 [3], and these ratios are even more predominant in rural healthcare delivery. The healthcare to population ratio for the 10 regions in Ghana is shown in Table I. The quality of healthcare delivery differs to a large extent across different regions of Ghana.

Urban areas have a good number of pharmacies, clinics and hospitals while rural areas often lack or have fewer of these facilities readily available. This causes patients in most rural areas to depend, to large extent, on traditional African medicine or travel long distances to access modern healthcare [4].

Furthermore, specialist physicians are mostly stationed at the urban centers. This implies cases which cannot be handled by physicians in the rural areas have to be referred to the urban facilities.

It is estimated by the Ghana Statistical Service [5] that about 6.8 million (23.4%) people living in Ghana are poor and cannot afford to spend GHS 4.82 (~USD 1) per day (GHS 1,760) in 2016/2017. Within that same period, it was estimated that 2.4 million people (8.2%) are extremely poor and cannot afford to spend GHS 2.69 per day and a greater part of these people are rural dwellers. Low level of income of rural dwellers means some patients may end up not following up on treatment of their ailments due to the associated cost of travelling to urban health facilities to seek medical intervention. To improve the delivery of quality healthcare in these deprived areas, there is the need for a system which will reduce cost while ensuring patients receive satisfactory healthcare. With the advances being made in information and communication technologies, telemedicine serves as a solution to these issues. Investments in large scale telecommunication infrastructure across Africa has been inadequate, partly as a result of wars and civil unrests in some parts of the continent. This development has been estimated to slow down economies and infrastructure building by up to seven years for each year in which there is unrest. Besides, in rural areas, where telemedicine will be most beneficial to the poor, the likelihood of it being provided is very low due to enormous infrastructural requirements and connectivity costs [6]. Internet connectivity is also low in locations outside the urban expanse [7].

Telemedicine technologies have been in use for some time in the developing world, but on a relatively smaller scale compared to developed countries. One major challenge for this is the relatively little contribution of governments in promoting telemedicine implementations, especially privately initiated telemedicine projects. Another challenge is low investment in fast internet and data transmission infrastructure, especially in the rural areas. Funding is also a challenge when it comes to telemedicine with a number of successfully piloted projects grinding to halt due to lack of funds to implement the project on a large scale.

Telemedicine initiatives in Africa receive lots of press coverage but often, few are sustained after the trial stages to be incorporated into the existing medical system. As a consequence, there is also very little published data on their operation [6]. There is relatively very little scholarly work proving the existence of telemedicine implementations in developing countries as compared to the developed world [8]. Thus, studies and reports on telemedicine in Africa are desirable.

TABLE I. HEALTHCARE STATISTICS FOR RESPECTIVE REGIONS OF GHANA [9]

Region	Population (2017)	Number of Health Facilities (2016)	Population to Doctor Ratio (2017)	Population to Nurse Ratio (2017)	Population (2019)
Ashanti	5,490,543	1501	6482	689	5,792,187
Brong Ahafo	2,723,048	725	11,891	670	2,850,607
Central	2,507,668	429	9,219	547	2,563,228
Eastern	3,099,637	884	14,219	704	3,244,834
Greater Accra	4,721,891	694	3,751	637	4,943,075
Northern	2,927,959	579	13,877	590	3,062,883
Upper East	1,216,681	337	29,675	422	1,273,677
Upper West	811,122	311	20,278	388	849,123
Volta	2,491,439	598	12,094	674	2,607,996
Western	2,954,789	757	26,862	728	3,093,201

II. TELEMEDICINE

Telemedicine is the application of information and communication technology to provide healthcare access remotely [10]. It includes diagnosing, treating and evaluating patients through information exchange remotely. It considerably cuts down the cost associated with providing quality healthcare especially in rural areas by eliminating the need to construct and staff new facilities, which developing countries like Ghana generally lack. Telemedicine systems normally consist of a communication device with software to support sharing of information as well as a secure network channel for communication. A secure channel is necessary to ensure confidentiality and privacy of patient information and health records. It is generally believed that ICT has the potential to improve clinical care and public health. In addition to helping with medical education, administration and research, appropriate use of ICT can improve access to healthcare, improve the quality of healthcare service delivery and also reduce the effect of global shortage of healthcare professionals. However, a number of questions still remain about the potential value to people in resource-constrained settings such as the developing world [11].

Telemedicine applications can be divided into three main categories. The first is the store-and-forward in which medical records and data (digital images, etc.) for non-emergencies are stored and sent to a specialist for diagnosis and prescriptions at convenient times. The second is the real-time interactive consultation. With this, services are provided in real-time using videoconferencing equipment at both ends for a variety of services including consultation and diagnosis. The third is remote monitoring, which helps the medical specialist monitor the condition of a patient using various devices remotely. Offering patient care over distance and possibly from another country raises issues such as liability, licensure, jurisdiction, quality and continuity of care, confidentiality, data security, consent, authentication and remuneration. The current practice in many telemedicine services is that the referring doctor keeps the responsibility of ensuring care is provided to the referred patient. The consulted doctor only offers second opinion advice which can either be accepted or rejected by the referring doctor [7]. Jurisdiction and liability remain with the referring doctor and his or her country in the case of cross border practice.

A. Store and Forward Technology

The store and forward technology involves a non-simultaneous communication between the patient and healthcare provider in which medical information, such as medical images are put together and sent to a doctor or medical specialist for evaluation offline at a convenient time. This category of telemedicine does not require the patient and healthcare provider to meet. A medical record in electronic form is included in the data sent, if possible. A key difference between the face-to-face patient-doctor meetings and store and forward telemedicine is the absence of a regular physical assessment. In the store-and-forward process, the doctor depends largely on a pre-recorded report, which could be in the form of a text message or email with images with or without audio or video data of a physical assessment. The store-and-forward technology is cheaper and simpler to implement than other forms of telemedicine. Medical information and clinical queries of patients can also be sent and responded to by healthcare providers at their convenience. This technology however, could reduce the level of diagnostic accuracy than a real-time system due to the possible difference in time between symptoms' occurrence and diagnosis [12, 13].

B. Real-Time Interactive

Real-time telemedicine involves a simultaneous communication channel between the patient and healthcare provider in real time. The patient transmits medical information and the healthcare provider receives it instantly. This technology involves over-the-phone conversations, online communication and visits to the patients' homes. A variety of medical activities such as physical tests, psychiatric assessments and medical history assessment can be done much like with the traditional face-to-face treatments. The real-time interactive technology allows healthcare providers to diagnose conditions of patients in remote locations in real time. However, it is more expensive to implement than the store-and-forward technology. A timing schedule is also required between the healthcare provider and the patient or a colleague healthcare provider for a successful consultation [12, 13].

C. Remote Patient Monitoring (RPM)

Remote patient monitoring, also called 'self-monitoring/testing', is a category of telemedicine application

which enables healthcare providers to check up on a patient remotely using various technological equipments. This application of telemedicine is mainly used for managing chronic diseases or specific conditions like heart disease, diabetes mellitus, or asthma. These services can be comparable to conventional face-to-face patient consultations and can also be economical [13]. Remote patient monitoring enables patients to be monitored outside the clinical setting to reduce cost of healthcare whilst increasing the quality of care [14]. The major features of RPM include remote monitoring and trend analysis of physiological parameters and early detection of deterioration which reduce the number of emergency department visits, hospitalizations and shortens duration of hospital stays [15]. Different applications of RPM introduce a number of variations in RPM system architecture. However, most RPM systems consist of four main components: a sensor to measure physiological parameters, data storage at the patients' end (an optional requirement), a central data storage and a diagnostic software [16].

III. Methodology

Literature was collected by searching indexing databases. Cited papers in articles considered for review were also collected. Papers and articles included for consideration provided information on telemedicine implementations in Ghana. Papers and articles presenting case studies of telemedicine implementations without describing the implementation itself were excluded due to the fact that we seek to discuss the telemedicine implementations in this paper.

IV. Applications in Ghana

There are a number of telemedicine applications which have been implemented in Ghana. We take a look at some of these applications based on the technologies used in deploying them in this section.

A. Store and Forward Applications

The following projects discussed below are examples of store and forward application Telemedicine implementation in Ghana.

1) Asynchronous remote medical consultation: Remote Asynchronous Communication for Healthcare (ReACH) was set up to resolve the failures in the existing patient referral infrastructure, by presenting an online system in which rural doctors in Ghana can input case information as text or images, and forward, or "assign" that case to a specialist in one of the central hospitals. The store-and-forward nature of the entire system makes it an inexpensive tool that does not require high speed internet connections and functions effectively over e-mail as well as through a web-based portal. A further step is taken to leverage the delay-tolerant networking (DTN) architecture, which would allow computers without intranet or internet connection to be updated via a USB key. The shortage of medical specialists in the country is addressed by enabling volunteer specialists around the world to access the system, to provide a second-tier group of consultants in the event that the medical specialists in Accra are unable to handle a particular case due to their lack of time or expertise. Doctors are also allowed to easily communicate with colleagues in a non-case-specific manner. To ensure accountability for specialists in the system, information seekers are allowed to assign their cases to a few potential specialists, while the system does the final assignment to one of the specialists (to balance load automatically between the specialists). The system is capable of using already existing social connections between information-seekers and specialists to ensure seekers know the specialist attending to them to make specialists more responsive to persons, instead of to a system. On the other hand, information-seekers have a publicly available profile with uniquely identifying data, making them accountable in the system. This makes it easy for a specialist know the outcome of a particular case. All cases were allowed to pass through a first assignment tier with Ghanaian specialists before foreign specialists were engaged when there was an overload of work on the Ghanaian specialists. Participants in the system as much as possible had some amount of field knowledge of the medical practice in Ghana, to ensure they were familiar with the conditions and the people they would be working with. In cases where this was not possible, a full-day training session was proposed with the local doctors and made available to specialists abroad [17, 18].

2) Web-based tele-ophthalmology system: A web-based tele-ophthalmology system was set up to allow eye practitioners to share photos with a case history online to receive help on the case from a specialist at Moorfields Eye Hospital in London. It involved a number of referring centers across Africa including Korle-Bu Teaching Hospital in Accra. The online platform uses a secure method based on SSL encryption for information sharing, to preserve data privacy. As part of ethical requirements for research, patient participating in the teleconsultation provides a signed consent form before participating. The doctor seeking help provides a brief case history of the patient which includes the current problem, planned treatment of the problem and research undertaken concerning the problem. A maximum of four images can be uploaded with the case history file. Internet access was provided in each participating center as well as training on capturing images. Digital cameras are used to capture images. When a practitioner uploads a case on the system seeking help, an email is sent automatically to the specialist from whom help is sought, notifying them to respond on the system. When a case is also responded to, an email is sent to the practitioner stating the case has been responded to. The site supervisor and doctors related to the case are the only ones with access to that case [19].

3) Sene PDA: The Sene PDA project was aimed at improving healthcare delivery at the Community-based Health Planning and Services (CHPS) zones via the use of information technology. It was one of the early mobile health initiatives in Ghana and was first deployed in 2004. It was introduced to enable reports used to make decisions by Community Health Officers and District Health Managers to be generated accurately with the aid of technology and to

reduce the time spent by the concerned parties to generate monthly reports on services provided. It also helps to better increase following up of mothers and children who have registered for services and reduces the rate of dropouts for immunizations and safe motherhood services [20, 21].

4) Mobile technology for community health (MOTECH) in ghana: MOTECH was introduced to enable the quantity and quality of prenatal and neonatal care in rural Ghana to be increased with the aid of mobile phones. The goal of this was to improve healthcare for mothers and their new-born babies. It has two major components: Nurse Application and Mobile Midwife Application. The Nurse Application helps community health workers monitor and record the care given to newborns and women in the rural areas. Each rural facility was provided with low-end mobile phones with the Nurse application installed on it. With this application, the health worker is able to record data about a patient's visits to the clinic and also query the MOTECH database to retrieve details of patients as well as lists of patients due for care and women due for delivery.

The Mobile Midwife application helps pregnant women and their families to receive voice messages or SMS messages with information about their pregnancy each week. Information provided through this channel includes reminders for seeking specific healthcare, advice to help with challenges associated with pregnancy and educational information to promote good health practices [20, 22-24].

5) Onetouch medicareline: The OneTouch MedicareLine program was developed to offer free calls and SMS messages between registered physicians and surgeons in Ghana. The main focus for its implementation was to reduce economic barriers associated with the use of mobile phones, and not on technological innovation. After registering with the system, a doctor is provided with a sim card. The sim card can be used to call other participants on the program free of any personal charges. This can save cost significantly, given the high cost of airtime especially in Ghana. As part of the program, the Ghana Medical Association was provided with a computer terminal to broadcast messages to participants of the program, alerting them of updates to the system. Future phases of the program envision new technological interventions. A second phase of the program was planned, which would include participants receiving free multimedia messaging service (MMS) to enable phone consultations be done with photos as well as the ability of the medical service and concerned government organizations to get data from participants via SMS messages. A third phase was also proposed to include a partnership with hardware mobile equipment vendors to provide each participating doctor with a smartphone preloaded with medical reference material [20, 25].

6) mPEDIGREE technology: The mPedigree technology was started to curtail the effects of counterfeiting in the health industry. Counterfeit drugs are a major concern in the health sector and have cost a lot of lives, jobs and revenue to genuine drug producers. The mPedigree system works with mobile network providers in storing a central registry which contains information of product brands of participating pharmaceutical manufacturers. In collaboration with the participant manufacturers, each product produced by these manufacturers has a concealed 12-digit number which is revealed by the consumer at the point of purchase. This number is unique and serves as an identity for each product. To check for product authenticity, the consumer sends the 12-digit number to a short code at no personal cost. If the product is genuine, a reply will be given containing unique details of the product, else it will be confirmed as a counterfeit product. Aside pharmaceutical products, the technology works with various other products to authenticate them and counter the deleterious effects of counterfeit products on the end users [20, 26].

7) The ghana consultation network (GCN): GCN was introduced in Ghana as a computer-based system providing medical consultation among doctors over a network. The aim was to enable doctors in Ghana to consult with each other, as well as with doctors across the world. Doctors are able to login into the system via a web-based user interface through a local server (located in participating hospitals) or through public servers hosted with Internet Service Providers. Provision of local servers enables availability of network connectivity in the event of unreliable internet connectivity. The system is presented as a social networking platform, one for medical consultation with both professional and social colleagues due to the fact that doctors already view consultation as reaching out to personal contacts. The system inculcates two modes of communication, a highly structured consultation mode for specific patients which works like an electronic case history and an unstructured discussion mode which works like an online forum. SMS messages and email messages have also been incorporated into the system for notifications of updates due to the widespread use of mobile phones. A number of doctors have been enrolled so far on the system, including doctors from Ghana, USA, South Africa and Nigeria. GCN was implemented after four iterative rounds of design and fieldwork. It began with an exploration of needs, some design exercises, a pilot deployment and the current deployment. Although the field survey focused more on rural hospitals in the northern part of Ghana, current deployment of the system is in the southern part of Ghana due to the ease of accessibility, with plans to extend the system to the north [20, 25].

8) SATELLIFE PDA project: The SATELLIFE PDA Project was setup to explore how Personal Digital Assistants (PDAs) could be used to address the digital divide between health professionals in Africa. Satellife conducted a pilot test in December 2001, in conjunction with the American Red Cross, to determine how effective PDAs were for field surveys related to measles in Ghana. Thirty volunteers from the Ghanaian Red Cross were trained over two days, and they encountered no challenges using the PDAs, even though a number of them had never used computers prior to that. Within the course of just three days, over 2,400 surveys were

completed, where previously only 200 surveys would have been completed with the traditional pen and paper method. The entire pilot deployment was finished within a week, with the ease and unprecedented speed of gathering data. The project produced very strong proof of the value of PDAs and technology for data gathering and reporting. A service known as Healthnet was also established at the medical school to provide access to medical information and electronic conferencing [20, 27].

9) Vodafone healthline project: Vodafone Ghana launched a medical health-oriented initiative named "Healthline", aimed at educating and informing the Ghanaian public concerning important health matters. The project attempts to answer health questions from Ghanaians in the form of a television and radio shows. According to Vodafone Ghana, the project is expected to educate the Ghanaian public and clarify certain health related issues and practices. There is also a feature known as Healthline 255, where accurate expert medical advice is provided by medical experts to people in need of good quality healthcare by medical experts from the convenience of their phones [20].

10)Electronic health information and surveillance system (eHISS): The Electronic Health Information and Surveillance System (eHISS) was developed and operated by Viamo, a Ghana-based company. The system was developed to assess the symptoms of sick children through mobile phones and also to provide tailored health advice to their caregivers. An automated interactive voice response system based on a clinical algorithm presents a number of questions sequentially to the caregiver to be answered, after which information on the disease symptoms and geographic location are gathered. The clinical algorithm was designed based on local assessments of clinicians' reports and recommendations and the Integrated Management of Childhood Illness Chart Booklet (IMCI) [28]. The algorithm was developed over a period of two years with the help of communication researchers, biostatisticians, epidemiologists, public health experts and clinicians.

When a call is connected with the system, there is a brief introduction and instructions are given to the caregiver on what to press for a 'yes' or 'no' response on their mobile phones. The first set of questions posed to the caregiver seek to determine if there are any 'danger signs' as indicated in the IMCI guideline, taking into consideration the age of the child. The next set of questions aimed to determine the exact symptoms the child was exhibiting. Further questions sought to determine the severity of the child's condition. A caregiver is required to give an answer to all the questions asked by the system, to enable all symptoms to be captured to ensure accurate advice is given after the symptoms are assessed [29, 30].

11)District health information system (DHIS 2): The District Health Information System (DHIS 2) is a web-based health information system with a centralized database to enable generation of reports and use of health service data from health centers. At the core of the system is a lightweight Microsoft Excel-based tool for ease of data input. Data in the database is stored in independent reporting forms according to the health facility the data is from. The system enables data to be analyzed from different health facilities or regions and to generate reports for centralized decision making by healthcare managers [31, 32].

B. Real-Time Interactive Applications

The following real-time interactive Telemedicine implementations have been piloted in Ghana:

1) Millennium village health system: The Millennium Village Health System (MVHS) is a core part of the Millennium Villages Project (MVP) to attain the Millennium Development Goals (MDGs) in low-income rural Africa. The MVHS is aimed at obtaining universal health coverage of primary health services to achieve the MDGs in healthcare, including a reduced child mortality rate and a reduced maternal mortality rate in relation to a baseline. The main strategy is to guarantee widespread access to health services without charge to patients at the point of care, with a continuous delivery of services between the household, clinic and the referral hospital. The MVHS encourages the continuous real-time collection and feedback of health data, including the recording of all the important events and verbal autopsies, to allow the continuous modification and improvement of methods to enhance health outcomes. Currently, the MVP is running the Millennium Village Global Network (MVG-Net). The aims of this network are to enable community health workers with the aid of MVP clinical facilities, to enhance the care given to patients continually, greatly improve the quality of data collection and reporting, and assist in the assessment of the MVP's progress towards enhancing the healthcare provided at MVP community sites. The MVG-Net has an open-source electronic health delivery platform known as OpenMRS which stores data for managing patient care, program evaluation and monitoring, decision making, and management. It enables a facility-based data storage of individual-level data, community-based data capture of individual-level information, data storage of individual patient health records, and an automated scheme for aggregating data and generating reports and feedback to health care providers and managers. ChildCount+, a program running under MVG-Net, is an SMS-based system that helps collect data for community health workers to monitor pregnant women and children under 5 years of age. As part of the test, the mClinic software was designed for midwives in Bonsaaso of the Ashanti Region of Ghana, to use to enable them have access to the MVG-Net. mClinic works on inexpensive android-based devices and allows midwives to obtain data [20, 33, 34].

2) Novartis: Novartis pilot project was intended to extend access to quality healthcare for people living in remote rural areas, to reduce time and cost of transportation and to eliminate unneeded referrals. It was developed to allow for

centralization of healthcare expertise with digital technology. Later, the project was expanded in 2015 to cover the entire Amansie-West district in the Ashanti Region. Mobile technology is used to connect community health workers based in rural, remote areas to experienced healthcare professionals via 24-hour teleconsultation centers. These healthcare professionals guide and advise the community health workers in their patient care to improve the quality of healthcare patients receive. This helps to reduce unnecessary referrals and also allows for immediate support in the event of medical emergencies. The project was launched in cooperation with the Columbia University Earth Institute's Millennium Promise, the Ghanaian Ministry of Health, National Health Insurance Authority and Ambulance Services of Ghana, and Ghana Health Services [35].

3) Pan african eNetwork: The Pan African eNetwork is a project initiated to help impart quality education to 10,000 students across Africa over a period of five years. Students were to be taken through various disciplines from some of the best universities and educational institutions from India. Aside this, telemedicine services are provided through online medical consultation to medical practitioners in Africa by medical specialists in India in various specialties [20].

4) Sanford: Sanford Health Enterprise is a non-profit rural healthcare organization based in the USA. Sandford began operations in Ghana in 2012 to help with Ghana's health system and works with over 300 health professionals. Sanford operates through at least 360 clinics in Ghana in collaboration with the Ghana Health Service and the Ministry of Health, and offers a wide range of services which include education, specialty hospital care and primary health care. Sanford operates both real-time and store and forward telemedicine in Ghana. Sanford uses EMR (Electronic Medical Records) to create a paperless system with easy and effective access to patients' records across their working sites. Software of the system needs a dedicated internet connection, a camera, a transmitting stethoscope software and an audio-video call system capable of two-way interaction. Some challenges facing their telemedicine initiative in Ghana include limited availability of internet connectivity especially in the rural areas, unstable electricity in rural areas, many diverse languages and inadequate medical facilities in rural areas [36].

5) Mahiri: Mahriri Mobile Services began a project to equip healthcare givers in remote areas in Ghana with tablet devices from Telmedx. These tablet devices are capable of providing high quality live video connection to doctors in Tamale and Nsawam to seek medical advice without them having to travel to those locations. The system provides the ability to treat medical conditions of all forms that would normally not be handled by physicians.

Patients are attended to in their homes, in remote clinics, in schools, or during community gatherings by traveling nurses who have been trained to use the technology, which was developed by Telmedx, an organization in San Diego, California. The system allows a doctor to examine patients over high-quality cameras of mobile devices using a web browser for real-time medical consultations. Doctors can also take high-quality photos of patient conditions from a web browser by controlling the backup cameras attached to the mobile devices remotely. The live video and still photos can be viewed beside each other on the computer screen, and can easily be saved to the medical records. The Telmedx mobile video platform also gives groups of doctors and specialists the ability to watch the same live video. Doctors are able to capture photos for closer analyses and efficient consultations. The mobile telemedicine program has been active in Ghana for quite a while, and has been lauded by doctors for its high quality of videos and photos [4, 20].

6) Family health hospital telemedicine: The Family Health Hospital in Accra launched a telemedicine center to grant patients access to medical experts and also to improve medical education in the country. The facility is furnished with video-conferencing systems and monitors, and is also aimed at enhancing medical training at Ghana's first private medical school, the Family Health Medical and Nursing Schools, which is a part of the Family Health Group. The center was set up as part of a collaboration between the Family Health Group Apollo Hospital in India and Airtel Ghana. The facility takes away the need for patients in the country to travel outside the country to seek specialist medical care. Patients only need to book an appointment with the hospital to have access to a live medical consultation with doctors in USA and India [37].

V. Discussion

There have been a number of telemedicine applications implemented across Ghana. However, there is a scarcity of literature covering some of these implementations as shown in Table II. Most of these implementations were done using the store-and-forward technology. This development is attributed to the relatively low and ease of implementation of the store-and-forward method. It was seen to be convenient for both patients and healthcare givers because information was bundled together and forwarded to the specialist at a convenient time and analyzed by the specialist at a convenient time as well. Simple messaging applications on PCs and cell phones were also used to transmit the information, which eliminated the need for a high bandwidth internet connection. Other technologies are costly and requires high speed internet access, especially for the interactive technology. Though store-and-forward technologies are less costly to implement, they take away one important aspect of telemedicine, live remote diagnostics.

The real time interactive technology has been also implemented by some organizations as well. VoIP and video calls demanded the use of high bandwidth internet access. This proved a bit of a challenge because of the unavailability, or limited availability of high-speed internet connections in the rural areas. Specialized applications which provided the ability to make VoIP and video calls were also used, which meant either buying the software, or building it from scratch, in order to have a dedicated channel for communication, instead of relying on what is offered to the public for general use.

Equipment for this, which includes cameras, PCs, servers, also added to cost in implementing telemedicine with this technology.

Remote Patient Monitoring (RPM) with miniaturized devices was the technology not seen in use in Ghana. This form of RPM requires the use of miniature sensing devices which are wireless network aware to record and transmit data to be analyzed by a diagnostic application or by a medical specialist without the patient having to visit the clinic. The challenge here is the relative scarcity and cost associated with getting many of these devices for various medical conditions and maintaining them to ensure they are always functioning properly. This challenge, as well as the need for reliable internet connection for data transmission in real time when necessary and a diagnostic-capable software able to analyze data collected making it difficult to implement. The major challenges facing telemedicine implementations in Ghana are:

- Low investment in fast internet and data transmission infrastructure, especially in the rural areas.
- Funding to maintain and scale up telemedicine projects.
- Relatively little contribution by the government in promoting telemedicine implementations.
- Miniature devices which are used for Remote Patient Monitoring are scarce and expensive and are mostly specific-purpose devices.

Telemedicine is gradually gaining grounds in Ghana and the impressive data throughputs measured for deployed LTE and WiMAX networks in [38-39] show that state-of-the-art implementation of Telemedicine applications in Ghana is feasible with the connectivity possibilities 4G and 5G networks present. However, the pilot implementations reviewed in this study show that there is a lot more that can be done to improve it. Some recommendations that can be adopted to increase uptake of the technology include:

- More research should be done in the area of data transmission to provide the ability to have good quality VoIP and video calls in the presence of low speed internet connection. This will greatly reduce the bandwidth challenges associated with the Real-Time Interactive technology especially in the rural areas.
- The government and stakeholders should include and apportion funds in their budgets for the maintenance of telemedicine projects.
- The government should be more involved and formulate strong policies which will promote and ensure the sustainability of telemedicine applications.

  Devices used in RPM should be generalized to be able to sense information for a larger number of conditions. This will eliminate the need to have different sensing devices for different medical conditions thereby reducing the costs.

TABLE II. SUMMARY OF TELEMEDICINE APPLICATIONS IN GHANA

Project	**Area of activity**	**Period of activity**	**Population affected**	**Focus**
ReACH	Upper West Region	2008 -	>50,000	General
Tele-Ophthalmology	Accra	2003 -	>100,000	Focused on eye care
Sene PDA	Sene	2004 -	>50,000	Focused on immunization
MOTECH	Kassena-Nankana, Awutu Senya, Gomoa West, Ada, South Tongu	2010-2014	>22, 237	Focused on pregnant women and newborns
MedicareLine	Accra	2007-2008	>100,000	General
mPEDIGREE	Nation-wide	2008-	N/A	Focused on pharmaceutical drugs
GCN	Northern Ghana	2007-2008	N/A	General
SATELLIFE	Accra	2001	>100,000	General
Vodafone Healthline	Nation-wide	2011 till date	>100,000	General
eHISS	Agogo (Asante Akim North)	2015	>45,870	General
DHIS 2	Nation-wide	2011 till date	>100,000	General
MVHS	Bonsaaso	2012 - 2014	>30,000	Focused on pregnant women
Novartis	Amansie-West	2015	>100,000	Focused on pregnant women
Pan-African eNetwork	Kumasi	2007	>100,000	General
Sanford		2012	>50,000	General
Mahiri			>30,000	General
Family Health	Accra	2016	>100,000	General

VI. Conclusion

Telemedicine is being adopted to solve a wide range of problems in the medical field. There are many benefits Ghana as a developing country can obtain from implementing telemedicine on a nation-wide basis. With the advances being made in information and communication technologies, telemedicine applications are most likely to expand to many more areas and solve many more of the pertaining problems. Though telemedicine is still in its developing stages in Ghana, it has the potential to be very useful in delivering healthcare, especially in rural areas, given the fact that there is a shortage of medical personnel in the country.

This paper sought to present some of the applications of telemedicine which have been implemented in Ghana. Several telemedicine applications have been implemented in Ghana till date and have been discussed in this paper. However, there is a scarcity of literature discussing some of the implementations. It was realized that some implementations did not gain grounds in Ghana due to lack of funds and little government support and these are some of the challenges facing telemedicine implementation in Ghana. With an increased involvement of the government in this country, advances in telemedicine will no doubt be sped up, thereby mitigating a lot of the challenges facing nationwide implementations of telemedicine projects. It was also noticed that Remote Patient Monitoring involving automated miniature devices was not seen in use in Ghana. If used, Remote Patient Monitoring involving miniaturized devices has the potential to reduce drastically patient visits to clinics as well as forgetfulness by patients to check their vitals, thereby eliminating congestion in medical facilities as well as reducing the workload on healthcare givers.

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