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The role of internet of things to support health services in rural communities. A case study of Ghana and Sierra Leone

Alex Boakye^a and Omilola Babatunde Olumide^b

^aInstitute for Social Development, University of the Western Cape, Cape Town, South Africa; ^bManager, Public Health, Security and Nutrition Division, African Development Bank, Abidjan, Cote D'Ivoire

ABSTRACT

Incidence of preventable diseases in rural parts of Ghana and Sierra Leone is unacceptably high, which calls for innovative solutions to be directed towards addressing this issue. The intention of this research is to examine the potential contributions of internet of things technologies (IoT) towards health improvement in low-resourced settings with emphasis on transforming patients care and improving efficiency in rural Ghana and Sierra Leone. The research project investigates and identifies appropriate mechanisms by which IoTs technologies could be leveraged to mitigate health burdens in poor communities with emphasis on enhancing remote monitoring of patients health, increasing access to health information, training of healthcare professionals and reducing out-of-pocket health expenditure.

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1. Introduction

The use of information and communication technologies (ICT) to support healthcare services is advancing exponentially across the globe. This is particularly so because of the greater demands for improved and quality care, particularly for underserved communities. Moreover, achieving universal health coverage and ensuring that all persons have access to quality and essential health services have become critical health agenda around the world (Government of UK, 2019; Nambiar, Reddy, & Dutta, 2017). Recent data shows that close to half the world's population lack access to essential health services, while nearly 100 million people are pushed into extreme poverty annually as a result of out-of-pocket health expenses (WHO, 2019). Residents in underserved community bear the highest burden of this situation. This phenomenon has generated a lot of research interests on how to harness the potentials of today's emerging technologies to ensure health equity and improve health outcomes of people in remote areas.

In this study, we focussed on examining the role of internet of things technologies (IoT) towards improving health outcomes for residents in rural Ghana and Sierra Leone. In particular, we highlight some of the health technologies that are relevant for augmenting healthcare delivery in rural communities. In doing so, we draw lessons from developed and developing countries and identify appropriate mechanisms by which IoTs technologies could be leveraged to mitigate health burdens in rural Ghana and Sierra Leone.

The Internet of Things (IoT) refers to the use of intelligently connected devices and systems to leverage data gathered by embedded sensors and actuators in machines and other physical objects (Baker, Xiang & Atkinson, 2017; Barro, Degila, Zennaro, & Wamba, 2018). Within the healthcare sector, IoT uses connected medical devices with combined health applications to deliver quality healthcare and improve diagnostics. This development has the potential to resolve shortcomings of rural healthcare delivery. For example, it presents an opportunity to support a shift of treatment in primary care clinics and hospitals to home through the use of digital communication such as e-visits, e-prescriptions and remote monitoring. Meanwhile, there are barriers to the adoption of IoT in poor communities. Language differences, cost of adoption, or simply lack of telecommunications infrastructure often represent key barriers for ICT use in rural areas (Rothstein et al., 2016). On the other hand, issues of confidentiality, privacy, ethics and human resource capacity also slows effort to introduce new technologies in remote settings.

The rest of the paper is structured as follows: [Section 2](#) presents the problem statement. [Section 3](#) provides an overview of the state of healthcare in both Ghana and Sierra Leone. [Section 4](#) discusses the potentials of IoT systems for health. [Section 5](#) is on related literature. [Section 6](#) is on benefits of IoT to health. [Section 7](#) is the conclusion.

2. Significance of the study and research questions

Communicable diseases and other public health problems impose a heavy burden on rural communities in Ghana and Sierra Leone. The systems for delivering healthcare in these areas are often inefficient and ineffective, yet these shortcomings only underscore a small scale of the numerous challenges experienced by residents' in poor communities. Adopting innovative technologies offers enormous economic and social benefits. Internet of things health technologies can help to bridge the health divide between rural and urban healthcare centres. However to achieve this requires understanding the mechanisms through which they can be deployed to mitigate health burdens. Accordingly, this study focuses on the role of IoT in improving and addressing key challenges in healthcare delivery in rural communities with a spotlight on Ghana and Sierra Leone. Special emphasis is placed on how issues of limited access to health information, shortage of health personnel, and control of counterfeit products can be address. Drawing on current inefficiencies and shortcomings, an IoT solution is being envisioned in this study as powerful means not only for improving efficiencies in health service delivery but also expanding health access. The research questions address in this study are:

1. What are the existing health challenges faced by residents in rural poor communities that, if addressed will lead better health outcomes?
2. What are the key IoT health technologies that can be adopted to address health needs in remote communities?
3. What mechanisms are needed to guarantee successful implementation of IoTs health technologies?

3. Methodology

In order to address the research questions, our analysis integrates the concepts of interpretive approach. This approach is based on the assumption that social reality is not singular or objective, but rather influenced by human actions, experiences and social contexts, and is therefore best studied by reconciling the subjective interpretations of its various participants. The approach was adopted because it enabled the researchers to understand that social reality is better interpreted through sense-making process rather than a hypothesis testing process (Maskin, 2019).

We started our analysis by first mapping out prominent IoT technology platforms that have emerged to support health systems. We laid out the potentials it holds in respect to improving health and social care services delivery and based on these information, we find out whether they are applicable to rural settings. A key task in this regard consisted of conducting a review to underscore the health needs of residents in rural Ghana and Sierra Leone. Documents were reviewed using an analysis framework to classify key issues discussed in the texts, gaps in literature, research findings and the methods adopted by the research. Overall, 40 documents (32 publications/reports and 8 health policies) were included in the review. We included data on developed countries, complemented with further important information from emerging countries. The final product is recommendations on IoT technologies for the domain of health, looking especially at solutions to the identified needs.

4. The status of health in Ghana and Sierra Leone

Ghana operates a decentralised administrative structure that follows a four-tier system divided into national, regional, district, and sub-district levels. Healthcare is equally decentralised along these administrative structures with the community level serving as the first point of the primary healthcare system. Compared to most African countries, Ghana's health system is relatively better when measured along health indicators developed by the World Health Organisation. For instance in 2016, the WHO's health profile projected Ghana's average life expectancy to be 63 years old, surpassing the average life expectancy on the continent (WHO, 2018). This

notwithstanding, there are existing systemic challenges and barriers that impede the delivery of healthcare. For instance shortage of health workers remains a critical challenge. The ratio of doctors to the population stand at 1.1:10,000 inhabitants. That of nurses and midwives stand at 9.8:10,000 (WHO, 2018). The training of healthcare professionals is extremely low relative to the country's health needs. There are also notable inequities in the provision of healthcare in Ghana. For instance only 24% of births from remote areas are attended by a skilled health professional, leading to much higher infant mortality rates. Domestic health expenditure also account for only 1.09% of GDP, a figure which is below the regional average (World Bank, 2018). On top of these, the country faces a number of digital health challenges ranging from poor ICT infrastructure to shortage of skills. However, given the high uptake of mobile phones in Ghana, there is enormous potential to extend health information and services to the nearly 50% of residents in rural areas.

Sierra Leone on the other hand experience similar health problems like Ghana. The healthcare system in the country is heavily underfunded with high chronic disease burden and insufficient numbers health workers. The ratio of physicians to the population stands at 0.25:10,000, compared to 9.1 in South Africa (WHO, 2018). According to WHO estimates, the country has one of the world's highest maternal and child mortality ratio (WHO, 2018). Maternal mortality ratio in the country stands at 1120 deaths per 100,000 births compared to Japan with 5deaths. Child mortality on the other hand stands at 82 per 1000 births compared to Japan with 1.9 (WHO, 2018). There also exist high levels of inequities in terms of access to services as well as health outcomes among regions. A fundamental barrier to accessing health services is the high cost of services and the inability of the larger rural population to access service. Attaining adequate quality of healthcare is a recurrent issue in the country, which is often exacerbated by drug shortages and stock-outs. The country's Domestic General Government Health Expenditure (GGHE-D) as a percentage of Gross Domestic Product (GDP) is 1.85% compared to 6.13% in Botswana (World Bank, 2018). In 2018, the government launched the Sierra Leone Social Health Insurance (SLeSHI) scheme to address access to care with it associated high cost to reduce the burden on the poor population yet capacity in terms of numbers and distribution of health workers remain primary barriers to improving the healthcare in the country. Currently ranked 106 of 194 countries in terms of network readiness, Sierra Leone is not well placed to take advantage of the benefits of AI in their operations and delivery of public services.

Remote areas in these two countries bear the highest burden of these challenges adding to the compelling problems of limited infrastructure for communication, water, sanitation, roads and transport. To respond to these challenges demands adoption of innovative solutions such as Internet of things health technologies. The next section presents some of the key IoT health technologies that can be adopted to address health needs in remote communities.

5. Overview and potentials of internet of things in the delivery of healthcare in rural Ghana and Sierra Leone

Internet of things technologies have become more influential in healthcare due to four major shifts in the health industry: growing demand of personalised care, rising healthcare costs, inadequate health infrastructure and limited health workers (Nambiar et al., 2017; Saleh et al., 2018). Internet of things health technologies are part of the whole digital health ecosystem' which is define as the use of information and communication technologies to provide care, train healthcare professionals, track and monitor diseases (Hanson, Pupilampu, & Shaw, 2017). These platforms include mobile health (mHealth), ethalth, telehealth, digital imaging, eprescription, early warning systems etc. It also encompasses a whole range of components such as mobile applications, biometric skin sensor, short messaging service, interactive voice response, health management information systems, mobile diagnostic devices, wearables, drones and big data analytics. Their usefulness ranges from enabling healthcare professionals to bring care closer to patients to empowering patients to assume control of their own health.

In most rural parts of Ghana and Sierra Leone where access to essential health services is notable challenge, mHealth technology can provide remarkable opportunities. mHealth has emerged rapidly in many emerging economies due to the large penetration of mobile phones. In 2016, mobile phone penetration in Africa reached nearly 90 percent of the population (Allsop, Powell, & Namisango, 2018). This phenomenon has encouraged the development of low cost digital health technologies used to reach underserved populations and enabling people to self-manage their health and wellbeing. It is estimated that about 80% of residents in rural areas of Ghana and Sierra Leone own mobile phones (Abekah-Nkrumah, Guerriero, & Purohit, 2014; Wurie, Samai, & Witter, 2016).

Implementing mobile health in remote areas can be highly beneficial in the areas of delivering higher quality of care to patients, reducing health cost, increasing patient compliance and decreasing health disparities. Some African countries are already benefiting from the mhealth services. For example in Tanzania, Airtel Tanzania provides a free service that facilitates text messages about infant care to mothers and pregnant women. In South African, MomConnect a mobile messaging platform which is integrated with a national pregnancy registry and a help desk for questions and feedback has seen over 465,000 users adopt the service since its launch in 2016.

Telehealth is another IoT technology that enables the delivery of quality care to individuals located in areas with limited access to services. Telehealth allows health professionals to remotely offer care through the exchange of information with patient thus avoiding hospital admissions and improving self-care (Blusi, Dalin, & Jong, 2014). One fundamental challenge to receiving care in remote areas of Ghana and Sierra Leone is the lack of quality road infrastructure. Deplorable state of roads in rural areas increases the cost burden of patients in accessing healthcare. Even in places where roads are fairly in good state, limited ambulances contribute to missing emergency treatments. To mitigate this burden requires a new way of delivering healthcare and telehealth can be useful in this regard. It has the benefit of contributing to reducing transportation cost and increasing convenience of patients in obtaining care. Some advance countries have already integrated telemedicine in their healthcare delivery. The Korean UHealth program is a typical example. The UHealth program supports caring for aged and sick patients by virtually monitoring their vital signs and other critical health information. This can include blood pressure, blood sugar, body weight, cholesterol levels and ECGs. Monitoring can also include physical activity, exercise, nutritional intake and other lifestyle information that might be relevant to an individual's health. In 2015, the government of Kenya also introduced a national telemedicine strategy to extend health services to the poor and marginalised in remote areas (GBHealth, 2019). The strategy allows patients and healthcare providers in rural areas to use video conferencing to interact with experts at the national hospitals.

Electronic health records (EHR) and ePrescription also have the potential to address some of these fundamental problems like theft and corruption in rural healthcare. Electronic health records are computerised health record used to capture, store, access and share summary information (WHO, 2019). ePrescription on the other hand is a computer-generated order for a medication, transferred by electronic communication to a national or regional repository or directly to a pharmacy (WHO, 2019). Beyond the challenge of limited health infrastructure in rural Ghana and Sierra Leone, absenteeism, corruption and theft of limited medical supplies are serious problem in rural healthcare. According to a report by the United Nations Development Programme, theft has been found to increase when the potential benefit from theft is high, when the probability of detection is low, and when the expected penalty is minor (United Nations & Development Programme, 2011). Electronic health records (EHR) and ePrescription technologies can contribute to reducing costs and combating fraud and corruption in rural healthcare delivery.

Drone technology could also be influential in addressing the issue of delayed medical supplies in rural communities. Drones could deliver medical supplies and blood to patients in timely manner, especially for those in critical emergency situations. A typical scenario is a child who unknowingly drinks a poisonous substance in a remote village. A lack of swift medical attention will mean being in a life-threatening situation. With poor road infrastructure in such a community, delivering medication by car will be highly ineffective. The best alternative will be the use of drones which is less costly and less time-consuming. Drone technology can also be instrumental in home-based care for older and bedridden patients who may have difficulties to travel for long distance. For example, during the process of giving care, the medical professional can take blood sample and transport immediately by drone to the laboratory for analysis. Results with medications and antibiotics could be delivered back to the home by drone. Rwanda was the first African country to adopt drone technology for the transport of blood supplies and essential commodities to rural communities. In 2017, Tanzania government announced its plans to adapt the Zipline drone delivery system to enhance the delivery and access to essential medicines (GBHealth, 2019). In 2016, Matternet and UNICEF partnered to use drones to improve HIV testing and treatment procedures in Malawi.

Drone technology has been found to be more cost effective in delivering essential commodities than vehicles in one study (Tavares, 2019). This case study analysed the cost effectiveness of drones compared to electric vehicles for the delivery of biomedical samples in the city of Rouen (France) between three hospitals located in three different areas of the city. Results from the analysis revealed that delivery of biomedical samples with drones takes approximately 15 min, almost a third of 42 min estimated for vehicles. In addition, the delivery by

drones is also expected to be 60% cheaper. The cost per delivery by drones was also found to be 60% cheaper than delivery by vehicles. In effect, drone technology can serve as a viable means of leapfrogging the infrastructural challenges in rural Sierra Leone and narrow the healthcare divide between rural and urban population.

Investing in digital health technologies in these two countries is essential not only for securing the right to health but also has economic benefits. For instance, in Ghana the health sector contributes 2.1% to the overall Gross National Income (GNI) while in Sierra Leone the figure is 0.42% (Ghana Statistical Service, 2019; Natalie Sharples, 2015). However, in countries like Switzerland and Norway where digital health technologies are widely adopted, the average share of its healthcare to their economy is about 6% (OECD, 2019). Digital health technologies therefore have the potential to transform not only the health industry of Ghana and Sierra Leone but also its overall economy.

6. Related literature

The prevailing evidence regarding the link between internet of things technologies and health outcomes is relatively limited, as the main focus of several studies has been more broadly on the potential benefits of emerging technologies on productivity and growth. However, the limited evidence covering a number of countries, generally depicts the capacity of internet of things technologies to transform healthcare by enabling more effective integration of care (Baker, Xiang & Atkinson, 2017; Garrity, 2015).

For example, a study conducted in rural Tanzania shows that the use of telemedicine that links specialists to local areas via digital devices is allowing paediatric care to be offered to remote areas (Krüger & Niemi, 2012). This system appeared to work because the specialists involved had had some previous experience within the Tanzanian health system and therefore understood local situations. Another study examining the benefits of eHealth kiosks in rural India, revealed that the use of eHealth kiosks in seeking professional medical care by mothers concerning the care of their infants ultimately contributed to low infant mortality (Venkatesh, Rai, Sykes, & Aljafari, 2016). The authors presented that e-health kiosk enables the delivering of authenticated and accessible medical information. In Lebanon, one study revealed that eHealth facilitates equitable access to primary healthcare for those living in rural and refugee settings (Saleh et al., 2018). In a comparative study conducted among rural family caregivers receiving e-health caregiver support and those receiving conventional, non-e-health caregiver support, Blusi et al. (2014) discovered that the e-health support system improved care effectiveness particularly within the domains of preparedness, enrichment and predictability.

Investments in IoT health technologies have also been found to have social benefits. For instance a study in developing countries on the benefits of eHealth in 11 public and private healthcare delivery organisations of varying sizes and settings (rural/urban) revealed that investment in e-Health can contribute to 50–80% reduction in medication error rates, increase the use of formulary and generic drugs by 30% and increase patient screening and preventive healthcare procedures by 40% (Abolade & Durosinmi, 2018).

Other scholars suggest that IoT technologies could be used to provide better access to healthcare for those living in rural areas by allowing remote monitoring of non-critical patients at home rather than in hospital, thereby reducing strain on hospital resources (Baker, Xiang & Atkinson, 2017). The authors further provide that mobile health technology has the power to give patients in remote areas the opportunity to assume more control over their health thereby making them less dependent on health workers for health information. Essentially, it can offer access to healthcare resources whilst reducing strain on healthcare systems.

Trends in IoT-based healthcare have also been widely explored in recent times with much of these studies focussing on the development of platforms, new services and applications, interoperability, and security, among others (Bagula, Bagula, Mandava, Lubamba, & Bagula, 2018; Hanson et al., 2017). Moreover, policies and guidelines that enable easy and quick deployment of the IoT technology in the medical field have been analysed in many countries and organisations across the globe yet, the potentials of IoT technologies in the healthcare field remains in its infancy. At present, the pace of development in the whole digitisation ecosystem is increasing at an exponential rate, however experts wonder whether these developments could lead to little or complete transformation of the healthcare industry.

7. Roadmap for building and implementing resilient digital health systems in rural communities

Integrating Internet of things health technologies in rural healthcare systems offers new ways of improving healthcare in remote parts of Ghana and Sierra Leone. Within those communities, the primary focus must be on reducing healthcare burden, optimising efficiency of resources usage, expanding access to basic healthcare and reducing the shortage of well-educated healthcare professionals. Innovative and proactive thinking are key to building a supportive environment for the strategic implementation of resilient digital health systems in rural communities. Obviously, this must involve increasing connectivity, forging strategic partnerships, training of healthcare professionals and developing favourable legislation.

Increasing connectivity means expanding investment in communications technologies such as high-speed telecommunications networks, wireless systems and computer-based systems. This is an important strategy towards leveraging the benefits of IoTs. Limited internet coverage and poor connectivity are some of the fundamental problems experienced by health workers in rural areas. Even in places where network systems exist, cost is a significant barrier. To benefit from the opportunities of IoTs means African governments must make investment in digital infrastructures and the removal of key barriers to the deployment of high-speed networks to remote areas a development agenda. A critical area for policy action involves establishing national broadband plans with well-defined goals and targets. It is important to mention that in both countries, there has been effort to build knowledge and infrastructure capacity on which digital health interventions could take place. Investment in broadband internet infrastructure has significantly increased since 2010 in rural communities. ICT training has also been included in most educational curricula. Yet, most of these initiatives are private-sector driven, for-profit models. There is a need for a broader national broadband strategies and large-scale, state-sponsored ICT training and digital infrastructure investments.

The feasibility of using IoT technologies to support health systems in remote areas is also dependent on forging smart partnerships. Digital health is a nascent area for operators. It requires a mixed set of ICT and health skills and resources, and a partnership-based model. If IoT health technology opportunities are to be fully exploited, industry players will have to proactively build strategic partnerships and establish sustainable and cooperative health models. These approach could enable the pool of different strengths and capabilities that facilitate the delivery smart healthcare in remote areas.

Training and sensitisation are equally important elements for facilitating acceptance and use of new systems among health workers. Health professionals who experience difficulties in understanding and using digital health technologies, may have negative perceptions about its usefulness, and would be less likely to accept these interventions. Providing training can eventually contribute to shaping their digital literacy, reduces anxious about making errors and encourage the usability of digital systems and devices. Training should be reinforced by basic processes of inventory management, surveillance, contact tracing, prescribing medicines and stock distribution.

It is important to note that an ideal IoT health solution for rural healthcare works with mobile phones through the means of text or voice messaging. However, to ensure that messages are read and well understood, the solution must be adaptable to the cultural and linguistic attributes of the rural population. There are widely available health and wellness apps yet, many of them currently lack multilingual functionalities. Developing health apps with features that are adaptable to rural culture offers a great opportunity to accelerate its adoption (Rozen-Bakher, 2018). More importantly these solutions must be cost-effective.

Strong legislation, policy and compliance are essential for building resilient systems for IoTs health technology penetration in rural areas. Inadequate rules governing data storage, privacy and confidentiality issues can have implications for confidence deposed in the use of digital technologies. To stimulate quick acceptance of IoTs health technologies, authorities must ensure that strong legal frameworks exist to protect the rights of technology developers and users.

8. Conclusion

This study has shown that Internet of Things technologies have the power to improve health outcomes for people located in rural and remote locations, particularly for those with mobility problems or who find travel difficult. It has identify various domains by which IoT can support healthcare delivery. These domains include remote monitoring, diagnosis, care extension, inventory control and self-care. The study has also outline a number of roadmaps for building and implementing resilient digital health systems in rural communities. The study is meant

to influence policy on the adoption of IoT improving health in rural communities. The study can also help policy developers to recognise that emerging digital health technologies can contribute to improving equity in health by connecting underserved populations in rural areas with urban health facilities with highly qualified personnel.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributors

Alex Boakye is a PhD Candidate at the University of the Western Cape in South Africa.

Omilola Babatunde Olumide is the Manager, Public Health, Security and Nutrition Division, African Development Bank, Abidjan, Cote D'Ivoire.

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