



## Digital Health Inclusion: A Pilot Study of Health Services Deployment Using Communications Satellite for the Underserved in Nigeria

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## ABSTRACT

**Health service delivery in Nigeria is constrained by: brain drain, insufficient infrastructure and technology, poor and inadequate medical facilities and paucity of medical specialists in rural and remote regions - thus leading to a high rate of “medical tourism”. With increasing mobile phone ownership in Nigeria, mobile technology-based telemedicine has the potential to improve Nigeria’s healthcare delivery with enabling infrastructural facilities. In this paper, a pilot study that uses Nigeria’s communication satellite system for virtual Telemedicine connection between health practitioners and underserved communities using the “one2one” mobile telemedicine application is reported. This pilot study aimed to deploy Nigeria’s communication satellite system to enable virtual telemedicine connection between health practitioners and underserved communities using the “one2one” mobile telemedicine app. Successful deployment of a 1.8m VSAT dish at the pilot clinic and testing showed robust internet connectivity with a time delay of 250ms per hop. Furthermore, the One2one app was successfully installed on health practitioners’ tablets/phone and patients’ phone/tablets. Over 100 patients were treated using the one2one app connected through the satellite internet. The one2one app was highly rated by patients and healthcare providers in terms of usability with the highest score being ease of use 87%. This study shows that Nigeria’s communications satellite can be deployed to support mobile telemedicine as part of the effort to increase access to doctors and specialists in medically underserved areas of Nigeria.**

**Keywords:** Communications Satellite, Digital health, Telemedicine, Underserved Communities.

## INTRODUCTION

The 21st century, has witnessed the spread of the internet worldwide, thus the notion of digital health turned around positively. There was an overall spike in digital health services implementation in April 2020 during the COVID-19 pandemic from 1% to 78% according to Bestsennyy et al [1].

Digital health refers to the use of information and communication technologies in medicine and other health professions to manage illnesses and health risks and to promote wellness. It has a broad scope and includes the use of wearable devices, mobile health, telehealth, health information technology, and telemedicine [2]. Digital health is a discipline that includes digital care programmes, technologies for health, healthcare, living, and a society to enhance the efficiency of healthcare delivery thereby, making medicine more personalized and precise [3].

The introduction of digital health into the healthcare system/health sector was aimed at achieving some particular objectives. These objectives will serve as instruments for tracking the progress in its implementation. Some of the objectives include: improvement in the quality of care, improving access to healthcare, lowering the cost of healthcare, improving the patient experience, providing more personalized health care for patients, curbing any inefficiency in the healthcare system and enhancing the physician and other non-physician provider experience.

Furthermore, the advantages of this development may include but are not limited to: lowered healthcare cost, increased service quality, promoted digital economy, enabled personalized healthcare system, preventing the spread of infectious diseases, eased access to healthcare without barriers or limitations, eased access to patients' records for proper follow-up, database information for tracking healthcare delivery improvement.

The vast African countries could not make elementary provisions for efficient and stable healthcare systems which causes chaotic healthcare services. Unfavourable governance and poor management of resources also contribute to chaotic services in resource-constrained countries. The parlous state of the health care system has positively impacted medical tourism, causing over five thousand persons to embark on medical tours monthly. This leads to the Nigerian economy losing an estimated 1.2 billion US dollars to medical tourism annually [4].

Globally, there are 17 countries with significant practice of digital health, out of which there are 5 leading countries: Estonia, Canada, Denmark, Israel, and Spain [5].

This paper records the deployment of digital health using communications satellites to the underserved in Nigeria. These underserved communities include Internally Displaced Persons (IDP) camps, remote villages, communities with minority populations, disaster-affected areas, etc.

The rest of this paper is organized as follows: Review of related work presented in section II, Satellite e-health deployment in Nigeria is presented in section III, Results and discussion are presented in section IV, and the Conclusion is presented in section V.

## **REVIEW OF RELATED WORK**

The intricate nature of the health issues confronting Nigeria's underserved communities necessitates an interdisciplinary intervention. A proper grasp of the community context is required to achieve health equity. Hence, in this section, a review of related literature is provided which covers the review on digital health, the review on underserved communities, and the challenges facing the adoption of digital health in Nigeria.

### **Review of Digital Health**

Digital Health has various subdivisions or categories, this is really essential in providing adequate and suitable care for respective individuals as required. Some of the subdivisions are as follows:

#### **Remote Sensing and Wearables**

The need for real-time health monitoring, with the fast-growing population of aged persons, is really an issue of great concern in the healthcare system. This contributed to the wide application of wearable devices such as in healthcare and biomedical monitoring systems to provide personalized health services [6]. These wearable devices include but are not limited to Wrist-mounted devices, Wearable skin patches, Ultra-thin skin type sensors for temperature monitoring.

Recent proliferation in technology brought about the manufacturing of smartwatches that combines features of smartphones with continuous data monitoring, this led to their applications in remote health monitoring systems. This includes physiological monitoring, physical activities, and so on, which promote health monitoring [7].

### **Telemedicine and Health Information**

Telemedicine is a field under digital health which enables remote communication, monitoring, and scheduling appointments between patients and their care providers. Recently, more health care providers are offering to see patients remotely than physically. Telemedicine has numerous advantages ranging from comfort and convenience, containing infectious diseases, better assessment, easy access to a doctor and/or nurse up to severe condition management, and more [8].

Information technology is perceived as an instrument for alleviating the status of service, safety, and efficiency of healthcare systems. And benefits include the following among others; providing real-time decision support to clinicians, making cogent information available, and minimizing irrelevant testing [9].

### **Health and Wellness Behavior Modification Tools**

The benefits in imbibing healthy behavior in all ramifications of life are not limited only to individuals but also for the entire household and the society and/or community, even though not obviously noticed because it is not a physical development. Behavior is also said to be part of one's identity [10].

Behavior modification is a concept that is based on the principles of alteration and reformation with the view to changing undesired behavior and imbibing the desired behavior. Behavior modification techniques are essential tools for acquiring the desired behavior or discarding undesired behavior [10].

### **Digitized Health Record Platforms**

The adoption of digital health has led to the adoption of electronic health records (EHRs) and has been convincingly put to use in recent years. This has made the health care systems increasingly interdependent on the EHR capabilities, offerings, and innovations to better capture patients' data [11].

The electronic health records development was not targeted at engaging the patients but rather, it was developed to manage clinical information. However, patients' engagement got improved because they can access their health records data through online portals or mobile applications from the convenience of their respective locations [12].

### **Patient-Physician-Patient Portals**

A secure online platform (website) that gives patients all-time access to personal health records or information remotely from anywhere with an internet connection using mobile phones or computers. This information includes; recent doctor appointments and new appointment schedules, discharge summaries, dietary charts, medications, allergies and laboratory test plans, and test results evaluation [13].

Datareportal [14] showed that the internet users increased by 7.3 percent between January 2020 and January 2021. This rapid growth in the number of internet users is important in ensuring the adoption and efficient usage of the patient portal platform for easy access to care providers, personal health information, and convenience.

### **Decision Support Systems; Among Others**

Decision support systems implementation in healthcare systems are aimed to improve the quality of healthcare provided by assisting clinicians in important clinical decision-making [15].

Implementation of decision support systems across different settings has immensely turned around patient care processes, patient experience, healthcare expenditure, application of preventive medicine, and adherence to standards of medical practice [16].

The adoption and efficient functionality of digital health systems has some requisite factors that influence the adoption rate. These factors often contribute massively to the success record in the deployment. The flag-bearer countries in this practice are also the leading countries considering the factors that contribute to high adoption rate, such factors include:

### **Literacy Level**

The countries leading the index chart in digital health practice have a very high level of literacy with Estonia having 99.89%, Canada 99.0%, Denmark 99.0%, Spain and Israel having 97.78% and 91.75% respectively [1].

### **Internet Penetration**

Internet usage requires some levels of literacy for operation, high literacy levels will have almost a direct impact on the internet penetration rate. According to January 2021 statistics, Estonia has about 91.0% internet penetration rate while Canada, Denmark, Israel, and Spain have 94.0%, 98.1%, 88.0%, and 91.0% respectively [1].

### **Per Capital Income**

High income-country is one with a gross national income per capita income exceeding \$12,535 (International water Association). The leading countries are among the high-income countries i.e., their respective per capita income exceeds the threshold value. Canada's per capita income is \$46,370, Denmark \$63,240, Estonia \$23,220 while Spain and Israel have \$30,390, and \$43,290 [17].

### **Review of Underserved Communities**

During violent conflicts that result in the demolition of homes and properties, the majority of people who seek refuge in the government established IDP camps would have gone through many health challenges which are primarily a result of the absence of the United Nations convention principles on the establishment and management of the IDP camps. For example, in April 2015 UNICEF revealed that in IDP camps across Nigeria, about an 18% threshold of malnutrition is recorded, a statistic which obviously shows that this is higher than the global emergency threshold of 15% [18].

## **Challenges Facing Adoption of Digital Health in Nigeria**

Nigeria is the most populous nation in Africa with over 208.8 million inhabitants. Physical healthcare delivery to this large population will be almost impossible due to numerous factors ranging from inadequate facilities, unavailability of healthcare expertise, distance barrier, lack of effective and sustainable support systems.

Digital health practice in Nigeria since adoption is still in its infancy according to a survey by the GSMA association (2021). The government has not given a strong signal that it is open for digital business generally, so also at the state level making it a challenge to invest in it at this early stage. Though according to the respondents, the National Health ICT Strategic Framework 2015–2020 is robust but has not been implemented wholeheartedly.

## **JUSTIFICATION FOR DIGITAL HEALTH**

The need for Digital Health in Nigeria cannot be overemphasized, the fast growth of the nation's population, and the need to care for people in areas such as IDPs camps, retreat camps, and remote areas with less adequate healthcare access and poor healthcare facilities are major factors to be considered. Nevertheless, there are several factors affecting its implementation, adoption, and improvement, these include;

### **Low Literacy Level**

The literacy levels in Nigeria are experiencing inconsistency. It decreased from 70.02% in 2006 to 51.08% in 2008. September 2021 report showed that the literacy level in Nigeria increased by 8.94% from 51.08 in 2008 to 60.02% in 2018 [19]. This implies that the literacy level increased at an average of approximately 1% per annum during the decade. This literacy growth rate is way behind the growth rate in the frontline countries. Estonia for example has a literacy level of 99.89% since 2011 [1].

### **Low Internet Penetration**

According to January 2021 statistics, Nigeria has 104.4 million internet users out of 208.8 million inhabitants. There was a spike of 22% increase in internet users between January 2020 and January 2021, which was the effect of COVID-19. During this period most major businesses resorted to online mode of operation and many office jobs were done remotely via the internet. This shows that even after the spike only 50% of the population are internet users in Nigeria. The leading countries such as Spain and Israel have surpassed 90% internet penetration rate [1].

### **Lack of End-User Motivation**

In a developing country like Nigeria, end-users require motivation for the adoption of such liberating technology, especially in its early stage. This becomes a necessity because the literacy level is lagging far behind in the trail of the globally leading countries. This can be achieved through sensitization of the populace and gradual incorporation of the system into the healthcare system, this will provide a major motivating force.

### **Lack of Sustainable Support Systems**

The support system is a key crunode that ensures that the unwillingness to adopt this transformation in the healthcare system turns to willingness. A sustainable support system will alleviate the users' experience so as to bridge the gap between this digital approach to

access care and the low literacy level. This can be effectively achieved by setting up such a team that is readily available to render the necessary assistance upon request.

### **Poor ICT Infrastructures**

Information and Communication Technology in Nigeria cannot be likened to the global standard ICT, Nigeria is a developing country. As late as the 21st century about 48 percent of the total population of Nigeria still live in remote areas [19]. These areas are at a disadvantage in terms of good information and communication technology infrastructures and the issue has not been properly addressed. This will likely result in the dwellers of such areas not finding it beneficial to adopt such a sophisticated technology.

### **Lack of Training of The Frontline Workers**

Every patient needs assurance on their condition(s) or their situation. The health practitioners are the frontline workers in this regard and must be well trained. If the persons that are meant to reassure the patients on the reliability of the system and make them have confidence in the system lack the required knowledge to carry out the assignment, it is likely that the system will fail.

### **Lack of Adequate Technological Information**

There is no doubt that technological information does not spread at high velocity as does other news. And if it does spread eventually, it will not be as adequate as when it was aired. Also, on many occasions, a large number of people do not attach importance to it. Only the interested few amongst the 50% of internet users will access or receive first-hand news or information termed 'as e dey hot' meaning as it is being aired. Coming down to rural areas where they barely have any concrete means of receiving the news; it is difficult to have an impact.

### **Language Barrier**

According to Al Shamsi et al [20], the Language barrier is a pressing issue that needs to be addressed meticulously, else, it may create a conflict of understanding between the health practitioner and the patients thereby leading to a reduction in both sides' satisfaction and have an adverse effect on the quality of health care delivery and patient confidence in the service. Communication is a very important tool in understanding one another and getting the needful done, it also aides progress.

## **SATELLITE E-HEALTH DEPLOYMENT IN NIGERIA**

The health industry in Nigeria is riddled with numerous problems, some of which include brain drain, large infrastructural deficit, and inadequately skilled professionals. These problems are making the country lose \$1.3 billion annually to medical tourism [21]. Furthermore, according to National Population Commission, Nigeria [22], no less than 194 million Nigerians lack access to health insurance, which in turn deprives them of quality health care services.

### **Mobile Application**

To surmount these challenges, we propose the adoption of digital health services to bridge the healthcare gap in the country. Hence, in this case study, we conducted a medical outreach that leverages satellite broadband to provide digital health services to an underserved community

in Kaduna state, Nigeria. The community is remotely located, lacks access to adequate internet connectivity, and possesses no primary health care facility.

Unlike regular medical outreaches, this outreach provided health care services via a mobile application. The mobile application with a friendly Graphic User Interface (GUI) as depicted in figure 1 connects residents of the community to medical consultants stationed at various parts of the country. This approach eliminated the barrier of distance and solved the challenge of inadequate skilled professionals. The Mobile health application was used for communication between the patients and the doctor referred to as One2one. The one2one Healthcare Application has two applications, one for the Patient, one for doctor and the backend of the solution was built on AWS cloud. Patient and doctor applications were built for both IOS and Android mobile phones. The tech stack used on the backend has features like video calling based on WebRTC peer-to-peer (p2p) opensource technology while the chat feature is based on Extensible Messaging and Presence (XMPP) Protocol. The patient application has the capability to on-board doctors from the system database list. Consultation is available in the form of audio, video call and chat. Chat feature has the capability to send and receive images and video file and text chat. Doctor application has the capability to invite patients via phone number sms or by social media. Prescription management is available on doctor's app where doctor can add summary and prescription for a specific consultation. The patient application has the capability to view prescriptions with print or share feature. The Application solution is secured end to end with Health Insurance Portability and Accountability Act (HiPAA) of 1996 guide lines. The solution works on IP Internet networks. Cloud backend has its own database SQL, MongoDB, S3 buckets with end to end security. The whole solution is scalable and reliable. The cloud based solution can be deployed anywhere in the world.



**Fig 1: Picture of the mobile application**

## Mobile Application

Due to the sparse nature of internet connectivity in the community, the mobile application relied on satellite broadband to provide hitch-free internet connectivity. This connection was made possible via Nigerian Communications Satellite (NigComSat-1R). NigComSat-1R is a DFH-4 satellite launched in December 2011 after the failure of NigComSat-1. The communication satellite is a 9kW, quad-band spacecraft with a life span of 15 years [23]. Since its launch, NigComSat-1R has been supporting inadequate terrestrial networks. Hence, its services became functional in providing connectivity to the community. A Very Small Aperture Terminal (VSAT) was mounted in the community and connected to the satellite on the Ku band. The VSAT integrated an antenna, an orthogonal mode transducer (OMT) and a low noise block (LNB) to track, transmit and receive a signal from NigComSat-1R. The received signal was further transmitted to a satellite modem. From the Modem, the connection was extended to a wireless router to ease the connection process for support staff. A signal strength of 17.45dB was attained from the setup. To further ensure optimum internet connectivity, a dedicated bandwidth of 2Mbps uplink and downlink was allocated to the setup by NigComSat. Figure 2 shows a brief view of the connection setup.



**Fig. 2. Connection from the satellite to the community.**

The high-powered, quad-band (Ku, C, Ka, and L Band) geostationary satellite with a life span of more than 15 years with an orbital home of 42.5 degrees east was designed to provide strong footprints across the sub-Saharan region of Africa, Part of Europe and Asia to meet the telecommunication and broadcast needs of clients, service providers including Navigation Overlay Service (NOS) requirements similar to European Geostationary Navigation Overlay Services (EGNOS).

## Support Staff

The mobile health application and satellite broadband successfully delivered satellite-based digital health services to the community. However, the majority of the residents - only understand Hausa and don't possess basic digital skills. Hence, there was a language barrier and digital literacy gap. To fill this gap, the services of volunteer support staff were co-opted into the outreach programme. The volunteer support staff were people who have a good

command of both English and Hausa. Hence, they assisted patients in the use of the mobile application. They also assisted in measuring body weight, temperature, and blood sugar level.

### Process Flow

The modus operandi of the medical outreach is as follows and as depicted in figure 3: when a patient arrives at the outreach site, the support staff welcomes him/her and records their body temperature, body weight, blood pressure, and blood sugar level on the mobile application. Then s/he joins the queue until s/he is attended to by a doctor. The doctor communicates with the patient through the app, with the support staff serving as an interpreter. For physical examination, a video call is used to access the patient.

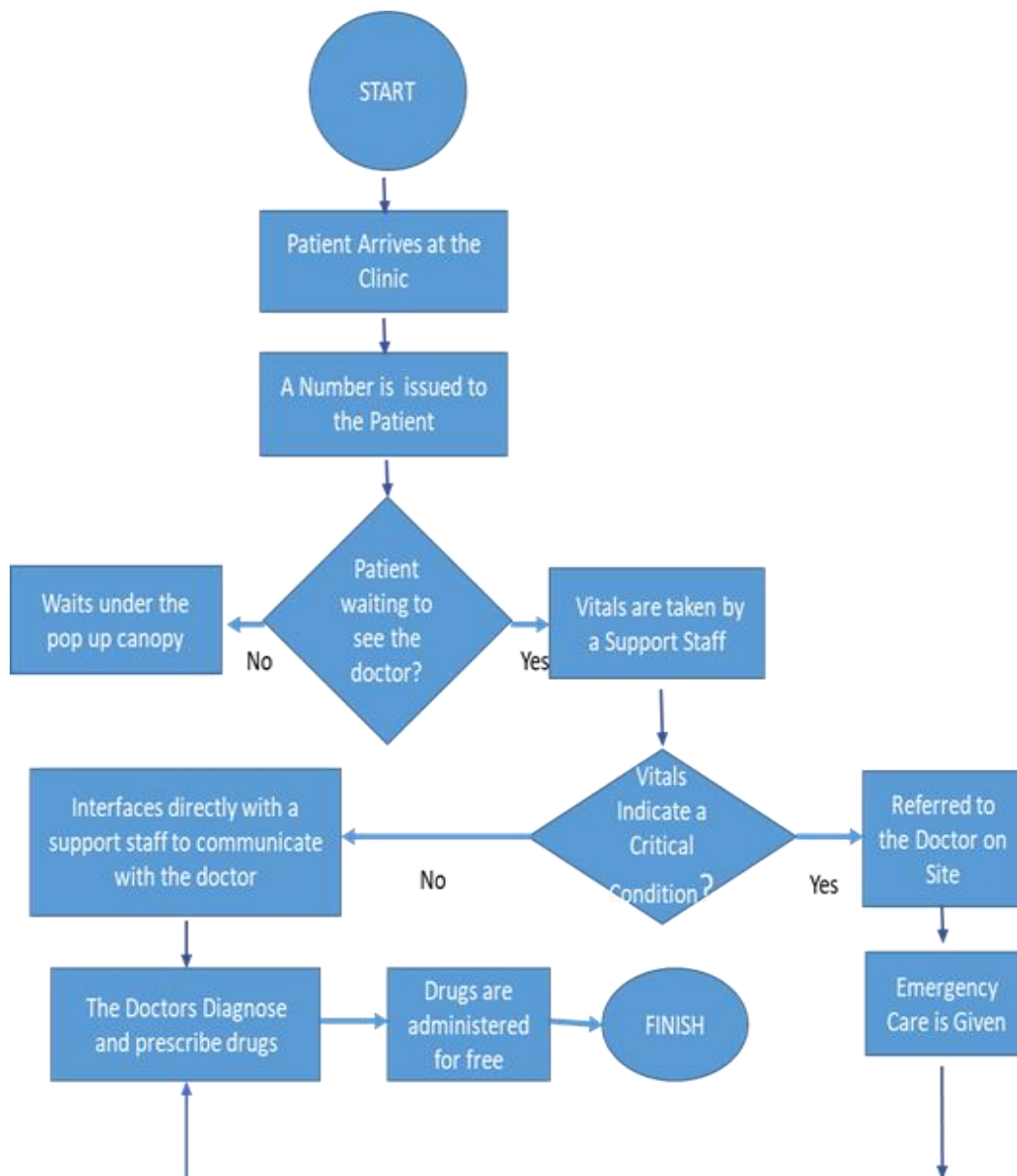


**Fig 3. Process workflow**

To assess the success and effectiveness of the exercise the mHealth Application, usability questionnaires designed by Zhou et al [24] were distributed to all stakeholders in the process (Patient, Doctors, and Support staff). Data Collected from the survey was analyzed using Microsoft excel and python software.

### **Questionnaire Description Provided as Supplementary Data**

A survey was conducted using paper questionnaires to determine the usability of the One2One mobile application, which was the tool used for communication between patients in Sabon Girmi and doctors in various parts of the world. It was conducted in Nigeria specifically in designated pilot clinical sites. As regards study population, participants were drawn from the technical support team of participating universities and organizations in Nigeria, clinicians from the pilot clinical sites and patients receiving services through the telemedicine service. Sample size was 11 covering technical support staff, administrative staff, clinicians, doctors and patients. This was meant to ensure data saturation cutting across gender, age, clinician cadre and technical support. Inclusion criteria age-wise is minimum of 18 years for a capacity to consent to the study while exclusion criteria is less than 18 years as part of the ethical clearance for the study granted by Research and Ethics Committees of Imo State University Teaching Hospital, Orlu, Imo State. Participants provided informed consent and their anonymity was protected. All survey and interview data were separated from any identifying information collected in the course of the study. Data was stored electronically with a two-factor authentication, in a password protected database.

Samples of the questionnaires are provided as supplementary Data to the paper. Appendix M1 provided as supplementary information is a consent form for participation in the research project stating title of the research, investigators, funding source, research study summary and authorization for participation; Appendix M2 is study form on socio demography covering gender, education, role in the project as a health worker, technical staff, administrator with years of experience including patient's years of experience in receiving medical care; Appendix M3 is interview guide for healthcare providers, technicians and administrators covering their involvement in the project, experience with the research project, and their thoughts about the research work on what is good, challenges and changes or additions they would want to suggest; Appendix M4 is interview guide for patients covering their involvement in the project, experience with the research project, and their thoughts about the research work on what is good, challenges and changes or additions they would want to suggest; Appendix M5 is mHealth Application usability questionnaires used by healthcare providers covering level and degree of their agreement or disagreement on usability, effectiveness, satisfaction etc; Appendix M6 is mHealth Application usability questionnaires used by patients covering level and degree of their agreement or disagreement on comfort, convenience, confidence on the mHealth app, usability, effectiveness, satisfaction etc; A total of 11 patients and health workers were recruited for the survey and analyzed using the six (6) questionnaire forms provided as supplementary data as Appendix M1, M2, M3, M4, M5 and M6 respectively.

## **RESULTS AND DISCUSSION**

The feasibility and general acceptance of digital health among members of underserved communities in Nigeria were evaluated in this work. A total of 449 patients were attended to in the course of the Connect2Recover (C2R) medical outreach programme held from February

25 to February 27, 2022. About 62% of the population of the patients were females while 38% were males. Their ages ranged from 0 to 80 with an average age of 23.

Samples of the questionnaires are provided as supplementary Data to the paper. In summary, from analyzed data as provided in Table 1, most respondents found the app easy to use. 100 percent of the respondents were satisfied overall with the app and 81.8 percent strongly agreed that the app provided an acceptable way to deliver healthcare services.

**Table 1. Survey Results of the Usability of the App.**

| S/N | Statements                                                                                         | Strongly Agree (%) | Agree (%) | Not sure (%) | Disagree (%) | Strongly disagree (%) | Not Applicable (%) |
|-----|----------------------------------------------------------------------------------------------------|--------------------|-----------|--------------|--------------|-----------------------|--------------------|
| 1   | The app was easy to use                                                                            | 90.91              | 9.09      | 0            | 0            | 0                     | 0                  |
| 2   | It was easy for me to learn to use the app                                                         | 72.73              | 27.27     | 0            | 0            | 0                     | 0                  |
| 3   | The information in this app was well organized, so I could easily find the information I needed    | 81.82              | 18.18     | 0            | 0            | 0                     | 0                  |
| 4   | The amount of time involved in using this app has been fitting for me                              | 54.55              | 45.45     | 0            | 0            | 0                     | 0                  |
| 5   | I would use this app again                                                                         | 81.82              | 18.18     | 0            | 0            | 0                     | 0                  |
| 6   | Overall, I am satisfied with this app                                                              | 72.73              | 27.27     | 0            | 0            | 0                     | 0                  |
| 7   | This mHealth app provides an acceptable way to deliver healthcare services                         | 81.82              | 18.18     | 0            | 0            | 0                     | 0                  |
| 8   | The app adequately acknowledged and provided information to let me know the progress of my action. | 72.73              | 18.18     | 0            | 0            | 0                     | 9.09               |
| 9   | The app improved my access to delivering healthcare services                                       | 81.82              | 9.09      | 0            | 0            | 0                     | 9.09               |
| 10  | I felt confident that any information sent to my patients using the app would be received          | 72.73              | 9.09      | 0            | 0            | 0                     | 18.18              |

A major requirement for the deployment of digital health is the presence of fast and reliable internet access, which is not available in most underserved communities in Nigeria. To deal with this challenge, this project employed the direct use of satellite broadband to provide internet connection at the site of the project, as opposed to the use of Internet Service Providers (ISPs). The satellite used was the Nigerian Communication Satellite (NIGCOMSAT-1R), which transmitted and received signals from a satellite dish located at the site of the

project through digital devices like smart phones, which broadcast requests to the satellite dish via a router to receive internet access on site [25]. This means that the bandwidth used for the project was a dedicated one, resulting in the achievement of seamless internet connection on site throughout the course of the project. The internet connection provided via internet service providers is usually not without disruptions because of the use of shared bandwidth services for an optimized return on investment.

As stated earlier, major challenges facing the adoption of telemedicine in Nigeria are language barriers and the low literacy level of the population, especially in underserved communities. This issue was resolved by the introduction of support staff to serve as intermediaries between the doctors and the patients. The support staff spoke both English and Hausa, the language spoken by the local community. The patients explained their symptoms to the support staff in Hausa, and they relayed the messages to the doctors in English. The success of this approach is evident from the percentage of people (81.82 percent) who strongly agreed that they will use the app again if given the opportunity. The video call feature of the mobile app also assisted for the purpose of physical examination, especially in the case of visible skin conditions. The engagement of support is also clearly a sustainable support system, because it bridges the gap between the digital approach to health care delivery and the low literacy level of the population.

To solve the problem of inadequate training of the frontline workers, we ensured that the support staff were literate, with a 100% of them having tertiary education. The doctors registered on the application were also carefully selected, and are all outstanding practitioners in their respective fields. More importantly, we ensured a strong interaction and information flow between the members of the team for the programme. Figure 4 below is a brief illustration of the information flow in the team:

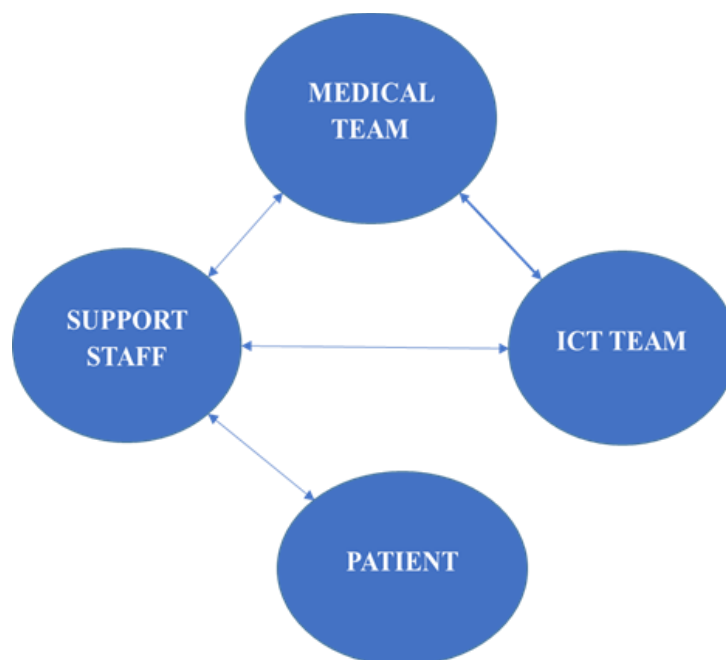


**Fig 4. Information Flow I the C2R Team**

Prolonged clinic waiting time is also a major cause of dissatisfaction among healthcare consumers. To prevent any form of bias in the order in which patients were attended to, numbers were given to patients on arrival at the clinic to ensure that patients were attended to on a first come first served basis. This also made crowd control easier. A waiting area was also provided at the clinic, which consisted of chairs arranged under pop up canopies to address the issue of over-crowding inside the clinic. Because of the organized method of attending to patients, each patient spent an average of seven minutes from the time they started a consultation with a doctor, to the time they were able to collect their drugs and leave the clinic.

The end-user motivation was high. This can be seen in the fact that not less than 110 patients were attended to on each day of the project. This may be attributed to the availability of free medicines at the clinic as prescribed by the health practitioners.

### CONCLUSION

In underserved communities across Nigeria, digital health presents a tool to close the gap between the inhabitants of such communities and medical personnel, who are usually based in urban locations. However, to ensure its general adoption, digital health practice in Nigeria must take into account, the peculiar challenges faced in our environment, such as low internet penetration, language barriers, and the lack of end-user motivation.

The findings carried out in the survey, the encouraging turnout of patients, and a large number of patients attended to during this project indicates that the adoption of digital health using communication satellites in underserved communities in Nigeria is feasible, highly recommended, and very likely to succeed. Despite the higher proportion of the survey respondents being satisfied with the mobile application and the process flow of the outreach, efforts can be made for the total automation of the process. Future work can therefore involve the incorporation of a language translator in a mobile application for e-health deployment. This will enable patients to express themselves better and directly to healthcare personnel, instead of through intermediaries.

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### Study Socio-Demographic Form

1. Gender
  - Female
  - Male
2. Age: \_\_\_\_
3. Education: What is the highest degree or level of school you have completed? *If currently enrolled, highest degree received.*
  - Primary school
  - Secondary school
  - Bachelor's degree/Medical Doctor/Nurse
  - Master's degree
  - Doctorate degree
4. Role in the project:
  - Patient
  - Healthcare worker (specify)
  - Technician
  - Administrative staff
5. For healthcare workers, technical staff, administrative staff: How long have you been working?
  - Less than 5 years
  - 5 to 10 years
  - More than 10 years
6. For patients: How long have been receiving care from the clinic/hospital/health center
  - Less than 5 years
  - 5 to 10 years
  - More than 10 years

### mHealth App Usability Questionnaire (MAUQ) for Interactive mHealth Apps Used by Patients

| #   | Statements                                                                                     | N/A                      |          | 1                        | 2                        | 3                        | 4                        | 5                        | 6                        | 7                        |       |
|-----|------------------------------------------------------------------------------------------------|--------------------------|----------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|-------|
| 1.  | The app was easy to use.                                                                       | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 2.  | It was easy for me to learn to use the app.                                                    | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 3.  | I like the interface of the app.                                                               | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 4.  | The information in the app was well organized, so I could easily find the information I needed | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 5.  | I feel comfortable using this app in social settings.                                          | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 6.  | The amount of time involved in using this app has been fitting for me.                         | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 7.  | I would use this app again.                                                                    | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 8.  | Overall, I am satisfied with this app.                                                         | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 9.  | Whenever I made a mistake using the app, I could recover easily and quickly.                   | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 10. | This mHealth app provides an acceptable way to receive healthcare services.                    | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |

|     |                                                                                                                                                               |                          |          |                          |                          |                          |                          |                          |                          |       |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|----------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|-------|
| 11. | The app adequately acknowledged and provided information to let me know the progress of my action.                                                            | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 12. | The navigation was consistent when moving between screens.                                                                                                    | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 13. | The interface of the app allowed me to use all the functions (such as entering information, responding to reminders, viewing information) offered by the app. | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 14. | This app has all the functions and capabilities I expected it to have.                                                                                        | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 15. | The app would be useful for my health and well-being.                                                                                                         | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 16. | The app improved my access to healthcare services.                                                                                                            | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 17. | The app helped me manage my health effectively.                                                                                                               | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 18. | The app made it convenient for me to communicate with my healthcare provider.                                                                                 | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 19. | Using the app, I had many more opportunities to interact with my healthcare provider.                                                                         | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 20. | I felt confident that any information I sent to my provider using the app would be received.                                                                  | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |
| 21. | I felt comfortable communicating with my healthcare provider using the app.                                                                                   | <input type="checkbox"/> | DISAGREE | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | AGREE |

In this questionnaire, 1 - strongly disagree, 2 - disagree, 3 - somewhat disagree, 4 - neither agree nor disagree, 5 - somewhat agree, 6 - agree, 7 - strongly agree

To determine the usability of an app, calculate the total and determine the average of the responses to all statements. The higher the overall average, the higher the usability of the app.