Overview of Satellite Communications and its Applications in Telemedicine for the underserved in Nigeria: A case study.

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Abstract — More than 2000 satellites currently relay communications signals to and from various locations across the globe for Internet, Broadcasting, Telephony and Navigation and the number is expected to quadruple in the next few years due to the proliferation of Global Non-Geo Satellite Constellations. With the potential to connect people separated by great distances, satellites are now being applied in telemedicine to make healthcare cheaper and more accessible. Nigeria has not been left behind in these efforts and has deployed the NIGCOMSAT-1R Communications satellite to provide telemedicine services to patients with health issues. Internally displaced women and children are globally the worst hit by the unavailability of healthcare services, with 87% of deaths in internally displaced persons (IDP) camps resulting from preventable illnesses. This presents a clear need for the adoption of telemedicine in IDP camps to provide Digital Health Inclusion services to the vulnerable citizens. We carried out a satellite-enabled telemedicine medical outreach at New Kuchingoro IDP camp in Abuja, Nigeria. A mobile application that allowed for text, audio, and video communication was employed using internet connectivity provided by the NIGCOMSAT-1R Communications Satellite. A total of 317 patients were attended to over the course of three days, and major issues prevalent in Nigerian hospitals, such as long waiting hours, were minimized. The medical outreach experience demonstrates the advantage of satellite broadband for telemedicine projects. It also proves the urgent need for innovative solutions for healthcare delivery in underserved and unserved Nigerian communities.

Keywords—Digital Health, Telemedicine, Satellite Communication, Internally Displaced Persons (IDPs), Mobile Health, Telecommunications.

I. INTRODUCTION

Satellite communication is an integral part of the global telecommunications systems that involves connecting two or more points on the earth via artificial satellites [1]. Currently, more than 2,000 artificial satellites orbit the earth and relay signals conveying voice, video, and data to different locations across the globe [1]. Satellites are useful in conveying data due to their wide coverage of the earth’s surface. Furthermore, satellites are useful in global positioning and navigation systems (GPS), weather forecasting, reporting on natural disasters, TV broadcasting, earth observation & surveillance including deep space missions and science. A satellite can perform these various functions by communicating with a ground station located on the earth’s surface [2].

In relation to satellite communication, telemedicine is the use of telecommunication facilities and infrastructure to exchange medical knowledge and deliver health care services over a long distance [3].

Telemedicine is a concept that originated about 30 years ago with the use of telephone and fax machines to provide expert-based medical care to remote locations [3]. Over the years, the implementation of telemedicine progressed from the use of wired communication media like; Plain Old Telephone System (POTS) and Integrated Services Digital Network (ISDN) to the use of wireless media like; GSM (Global System for Mobile Communications), General Packet Radio Service (GPRS), Universal Mobile
Telecommunications Systems (UMTS) and satellite communications [3].

Furthermore, telemedicine has advanced to a ubiquitous stage where the biomedical signals of patients can be gathered, transmitted and delivered to any place and at any time. These advances have birthed what is now known as mobile telemedicine [4].

According to the World Health Organization (WHO), at least half of the world’s population lack access to essential health services. In Africa, only half of the population has access to basic health care services. Considering the healthcare delivery gap, satellite-based telemedicine has the potential to bridge the healthcare delivery in Nigeria, Africa and the world at large.

This paper provides an overview of satellite communication, architecture, recent trends in design and technologies, some classification and regulatory issues, emerging applications including telemedicine. A medical telemedicine outreach event, using satellite communications, was carried out at an Internally Displaced Persons (IDPs) camp in a bid to provide Digital Health Inclusion services for the vulnerable citizens who lack access to healthcare services in one form or the other.

This paper is further divided as follows: section II discusses components of satellite systems, section III summarizes recent trends in satellite design and technologies, section IV highlights applications of communication satellites, section V reviews the application of satellites in telemedicine and section VI discusses a case study for the application of telemedicine in IDP camps.

II. COMPONENTS OF SATELLITE SYSTEMS

Satellite systems comprise numerous subsystems, which can be subdivided into Communication architecture, Satellite constellations, Spectrum, and Regulations [5]. A description of these system sub-divisions is given in this section.

A. Communication Architecture

A satellite communication system can transmit signals to various and remote parts of the earth. The system utilizes a space segment and a ground segment to achieve the transmission. The space segment houses the antennas, payload and satellite bus platform. The payload is channelized into transponders comprising receivers, mixers, power amplifiers and transmitters while the ground station comprises gateway stations, user segments and telemetry, tracking & Control (TT&C) stations [5].

The control, monitoring and maintenance of satellites is handled by the TT&C station, while the Gateway station performs backhauling and network access to consumers. The user segment provides a platform for consumers to interact with the system [5]. From the human angle, the satellite operator manages the TT&C section while the network operator manages the gateway stations and ensures connections to the user. The user (consumer) manages the user segment/platform [6].

B. Satellite Constellation Classifications

Artificial satellites are man-made bodies orbiting the earth and a satellite constellation is a collection of artificial satellites orbiting the earth as a system. A constellation is more advantageous because it can provide global or near-global coverage [6].

Constellations are classified relative to their positions above the earth’s surface. The possible positions are the Low Earth Orbit (LEO) with altitudes ranging from 500 to 900 km, Medium Earth Orbit (MEO) with altitudes ranging from 5,000 to 25,000 km and Geosynchronous Earth Orbit (GEO) with altitudes above 36,000km.

Latency of communication, signal attenuation and coverage of the earth are very dependent upon the position of the constellation. Satellites positioned in the GEO can cover a third of the earth’s surface but the downside is the high latency of communication [6].

Non-GEO satellites require less power, minimize propagation delay, and possess low communication latency but require more satellites for wider coverage [5]. When deciding which orbit to launch a satellite into, the major factor to be considered is what function the satellite is expected to serve. Non-GEO satellites are mainly applied in satellite radio services, military applications and commercial communication services. While MEO satellites are mostly used in Global Positioning and Navigation systems [5].

Beyond the regular circular orbits (LEO, MEO & GEO), there also exist highly elliptical orbits (HEO). HEOs such as Molniya orbits and Tundra orbits, these cater for the polar regions that are inaccessible to circular orbits.

C. Spectrum analysis

Satellite communications use electromagnetic (EM) waves to transmit information between space and earth. The frequency of an electromagnetic wave, represented in hertz (Hz), is the rate of reversal of the polarity in cycles per second [7].

Frequency band refers to a range of frequencies, while electromagnetic spectrum refers to all frequencies from zero to infinity. The Radio Frequency (RF) band is best for satellite communications because it allows for efficient generation of signal power, radiation into free space, and reception at a distant point [7].

Furthermore, the radio frequency band optimal for space-to-Earth applications is between 1 and 50 GHz. This band is categorised into Lower frequencies (L, S, X and C-bands) and Higher frequencies (Ku, K, Ka, Q/V bands).

Table 1 gives a summary of the various Satellite Bands, according to the IEEE standards [7].
The Consultative Committee for Space Data Systems (CCSDS) is a multi-national forum for the development of communications & data systems standards for spaceflight. CCSDS was established in 1982 to provide a forum for solving common problems in the development and operations of space data systems. CCSDS develops recommended standards and practices for data and communications systems. This forum helps to reduce costs by sharing facilities and promoting collaboration amongst space engineers [7].

The Research Project is funded by the International Telecommunication Union (ITU) Connect2recover research competition - Tele-medicine as a panacea to medical tourism in Africa exploiting communications satellite technologies.

### III. RECENT TRENDS IN SATELLITE DESIGN AND TECHNOLOGIES

In this section, recent trends in satellite design are reviewed. The review highlights reusable rocket launch vehicles, small satellites, Low-Earth Orbit (LEO) satellite constellation, advanced payload, satellite-enabled Internet of Things (IoT) and High Throughput Satellites (HTS) as trends characterizing the space industry [8].

#### A. Small Satellites (NanoSat & CubeSat)

Due to their small size, low cost, and lightweight, small satellites are utilized for varied applications such as communication, earth observation, remote sensing, space exploration, technology development and surveillance.

An analysis of the space market revealed the increased adoption of small satellites for research and development [8]. Furthermore, small satellites have received increased usage in the telecommunication and earth observation industry because constellations of small satellites can collect data more frequently than traditional satellites.

More than ever, small satellites have also enabled academia to participate actively in the space industry.

#### B. Satellite IoT

LEO satellite constellations provide numerous IoT applications due to their extensive coverage of the earth [8].

Currently, satellite-based IoT can complement existing terrestrial IoT in hard-to-reach/remote areas where the cost of installing base stations is expensive and unprofitable. [9]

Also, satellite-enabled IoT can serve as standalone systems in areas that humans cannot reach due to the topography and climate conditions. [9]

Hence, Governments and private sector investment in satellite technology are driving technological advancements in satellite IoT.

#### C. Advanced Payload Systems

Payloads constitute the foundation of satellite missions, and their growth is a top satellite technology trend. It is more cost-effective for start-ups to employ modular payloads than custom-made ones. Start-ups are using standardized payloads to improve the quality and capacity of satellites. As a result, sophisticated commercial off-the-shelf (COTS) equipment such as high-resolution imaging, spectrum sensors and foldable antennas, are finding a place in satellite payloads [8,10].

#### D. Global LEO Communications Satellite Constellations

In a bid to connect rural areas and improve quality of experience for users, global coverage of LEO Communications Satellites have emerged. LEO communication satellites are preferred over GEO satellites due to their shorter propagation delay, rapid global deployment and lower development cost [10].

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**TABLE I. SUMMARY OF FREQUENCY BANDS [7]**

<table>
<thead>
<tr>
<th>Band Designator</th>
<th>Frequency (GHz)</th>
<th>Wavelength in Free Space (cm)</th>
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<tbody>
<tr>
<td>L-band</td>
<td>1-2</td>
<td>30.0-15.0</td>
</tr>
<tr>
<td>S-band</td>
<td>2-4</td>
<td>15.0-7.5</td>
</tr>
<tr>
<td>C-band</td>
<td>4-8</td>
<td>7.5-3.8</td>
</tr>
<tr>
<td>X-band</td>
<td>8-12</td>
<td>3.8-2.5</td>
</tr>
<tr>
<td>Ku-band</td>
<td>12-18</td>
<td>2.5-1.7</td>
</tr>
<tr>
<td>K-band</td>
<td>18-27</td>
<td>1.7-1.1</td>
</tr>
<tr>
<td>Ka-band</td>
<td>27-40</td>
<td>1.1-0.75</td>
</tr>
<tr>
<td>V-band</td>
<td>40-75</td>
<td>0.75-0.40</td>
</tr>
<tr>
<td>W-band</td>
<td>75-100</td>
<td>0.40-0.27</td>
</tr>
</tbody>
</table>

D. Regulations

Regulations and standards are key requirements in maintaining an effective and peaceful space industry. Hence, the usage of common open standards is necessary to guarantee the ubiquitous nature of space devices and applications. Some of these standards and regulations include Digital Video Broadcasting (DVB), 5G NTN standardization and the Consultative Committee for Space Data System (CCSDS) amongst others [7].

Digital Video Broadcasting (DVB): these are the regulations and standards that guide and regulate the Television Broadcast industry. This standard covers the different broadcasting technologies. The DVB standards are managed by the DVB Project, an international industry consortium, and are published by a Joint Technical Committee (JTC) of the European Broadcasting Union (EBU), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). The standards developed under the DVB Project are i) DVB-S, DVB-S2 and DVB-S2X for Satellite TV; ii) DVB-C and DVB-C2 for cable TV; iii) DVB-T and DVB-T2 for terrestrial TV.

5G Non-Terrestrial Network (NTN) standardization: The 3rd Generation Partnership Project (3GPP) has concluded a feasibility study on the integration of satellite technologies into 5G communications. After the studies, the 3GPP also released a framework for the integration of Non-Terrestrial Networks into the 5G network. This framework would allow the use of GEO and the LEO in supporting Narrowband IoT (NB-IoT) and enhanced Machine-Type Communications (eMTC),
Concerns were raised over the coordination of GEO satellites and LEO constellations to avoid interference [10]. Resource allocation (time, frequency, power and space) is another factor to be considered in LEO constellation design [10]. Another concern is the affordability of Direct-To-Home (DTH) satellite broadband provided by LEO constellations [11]. Notwithstanding these concerns, LEO Communications Satellites paved the way for the emergence of space industry players like Starlink, OneWeb, Kuiper, Lightspeed and Galaxy Space (Yinhe). These companies are now acclaimed to be the Big 5 of the Global LEO COMSAT space industry [12, 14]

E. Digitalized On-Board Processing (OBP) Transponders
A transponder refers to a transmitter-receiver subsystem on board the satellite that processes, amplifies and retransmits signal spectrum (bandwidth). Advancements in Satellite technology have transformed analogue bent-pipe transponders to digital transponders [12]. This transformation birthed On-Board Processing (OBP) capabilities. OBP transponders made batch update to payload systems possible, simplified payload structure and eased business models [13]. Examples of advanced satellite transponders include; Multi-beam RF:IF switched transponder satellites and advanced regenerative on-board processing satellites etc [12, 13].

F. High Throughput Satellite s-HTS
Increasing and growing demands for broadband services and high-definition broadcasting from Geostationary Communication Satellites (GCS) have continually challenged satellite system design engineers to innovate and stretch the payload capacity and power capability of the satellite bus. This demand resulted in the reuse of a particular frequency over different geographical areas and the use of spot beams [12,13]. By re-using frequency, space engineers have now achieved higher throughput and lower cost per bit. Next Generation Ultra High-Density Throughput Satellites can provide speed clocking terabits per seconds (Tbps) i.e Viasat-3 on the Boeing 702 satellite bus [12,13].

G. Reusable Rocket Launch Vehicles
The recent trend is the usage of reusable rockets spearheaded by SpaceX reduces the cost per kilogram of launching space crafts, increases access to space and facilitates carrying out missions much more frequently [14]. Reusable rockets revolutionized access to space and enabled space startups and space tourism. Some key technology enablers of reusable rocket development are autonomous controllers and sensors for propulsive landings; parachutes with improved material technologies to reduce speeds after entering the atmosphere; airbags to absorb shocks when landing on hard surfaces or barges; autonomous barges and boats for rockets performing vertical landings at sea [14].

IV. COMMON AND EMERGING APPLICATIONS OF SATELLITES
Satellites have a plethora of applications in almost all spheres of life, ranging from military to agriculture and even government; satellites provide solutions to several challenges facing the world. In a comprehensive review and survey in [15], emerging applications highlighted include 5G Non-Terrestrial network, VLEO & SatCom-assisted aerial networks.

A. 5G Non-Terrestrial Network
The 3GPP has stated the critical role of satellite technologies in the efficacy of 5G technologies. This is so because satellite technologies can enhance the reliability of 5G networks by complementing terrestrial networks. Satellites would further guarantee the ubiquity of 5G by providing connectivity in un-served and underserved areas.

Furthermore, satellite communications would decongest existing terrestrial networks by supporting massive machine-type communication (mMTC) or Internet of Things (IoT). An example of this support: is the monitoring and management of livestock; likewise, in the transport sector to monitor fleet and vehicles.

In addition, satellite technologies could play a complementary role in autonomous vehicles; by providing backup to terrestrial networks in handling non-critical data and connections. Other use cases where satellites can be applied in 5G NTN are critical surveillance of oil/gas infrastructures, remote surgery and factory automation.

The successful deployment of 5G falls on the shoulders of national governments and regulators because they are expected to provide the new spectrum bands and operational guidelines for 5G deployment. The digital technology industry has recommended 3400-3800 MHz (C-band) on the commercial spectrum for the deployment of 5G NTN.

B. VLEO and SatCom-assisted Aerial Networks
Due to the technological advance of aerial and miniaturized satellite platforms, intermediate layers of communications have emerged between terrestrial and traditional satellites. Like satellite orbits, these systems are classified by altitude into; Very Low Earth Orbit (VLEO) satellites, High Altitude Platforms (HAPs), and Low Altitude Platforms (LAPs). The emergence of these platforms has given rise to multi-layer communications as depicted in Fig. 2.
On one hand, LAPs like Unmanned Aerial Vehicles (UAVs) and tethered balloons, can facilitate wireless broadcast and support. On the other hand, HAPs also known as pseudo-satellite have the potential to provide communications services on a regional scale [15].

C. Aeronautical and Maritime Tracking and Communication

Satellites have very important applications in aeronautics and the maritime industries. Integrating satellites into the current tracking systems available in the aeronautical and maritime systems would complement and upgrade existing tracking systems.

Currently, the Automatic Dependent Surveillance-Broadcast (ADS-B) used in the aeronautics industry provides navigation to aircraft by communicating with the air traffic controller and Air Traffic Management (ATM) network. However, communication is not efficient when travelling over oceans, deserts and waterways. Moving forward, the implementation of space-based ADS-B receivers using an LEO constellation of small satellites would upgrade existing Air Traffic Management networks.

Similarly, the Maritime Automatic Identification System (AIS) has adopted the use of satellite-based receivers to provide vessels and shore stations with information on identification and real-time positioning to avoid, not only ship collision accidents, but fleet management in real-time.

Furthermore, the AIS holds the possibility to facilitate unmanned transoceanic journeys, optimizes fuel consumption and allows for the direct use of electrical or solar power. In addition, satellite data could assist vessels and coastal authorities in managing busy port areas where conventional AIS receivers may not be able to handle the large volume of ocean traffic [15].

D. Earth Observation & Data Collection

Satellites are used to report the weather, monitor the oceans, detect changes in vegetation and analyse the damage done by natural disasters, like earthquakes or hurricanes.

More importantly, satellites provide objective data on events - showing trends and changes over time in a way that cannot be observed from the ground.

However, with the advent of machine learning, new-space companies are now providing insights and prediction models using data obtained from satellites. This way, natural disasters can be foreseen. Machine learning also plays a huge role in agriculture, because the likelihood of whether a particular geographical location can yield bountifully or not can be predicted using satellite data.

These new possibilities have now divided the space industry into the upstream and downstream sectors. The upstream deals with the operation and launching of satellites while the downstream collects data from the upstream and turns it into meaningful insights [15].

V. RECENT APPLICATIONS OF SATELLITES IN TELEMEDICINE

This section takes a closer look at the applications of satellite communications in telemedicine. It also reviews bottlenecks and challenges faced before, during and after the implementation of telemedicine systems based on satellite communications.

A telemedicine framework using mobile satellite communication was initiated in [16]. The framework identified emergency medicine in moving vehicles, physiological monitoring of pilots and emergency medicine during disasters as potential areas where mobile satellite communications can bridge the healthcare gap. It also outlined the opportunity for satellite communication to provide telemedicine services where cable and microwave communications are inaccessible [16].

This framework was implemented by providing paramedical care within a navigating ship, a moving vehicle and an aircraft flying an international route. During implementation, the system transmitted a colour image, an audio signal, 3 channels ECG and blood pressures from a moving craft to a specialist stationed miles away. Channel capacity, size of the system, reliability of vital sign transmission, real-time operation and electromagnetic interference were major challenges experienced during the implementation of this framework. An automatic repeat request and a buffer memory were incorporated into the transmitter and receiver to prevent transmission errors. Also, data were compressed using standard data compression techniques before transmission.

The need for legal backing in the transmission of sensitive medical data was noted [16], especially in climes where transmission of medical data might violate personal privacy laws.

The review of existing wireless telemedicine systems in [3] suggested collaboration between the government and private sector in promoting the applications of telemedicine to rural and urban health centres. This collaboration would help resolve legal concerns raised earlier. Collaboration between the private sector and the government would help surmount the high initial cost of telemedicine systems [3].

Furthermore, the overview recommended training of medical workers on the usage and benefits of wireless information technology in medicine.

A Medical Environment for Diagnostic Images (MEDI) telemedicine application was developed. This application leveraged the broadcast, multicast and wide-band capabilities of satellite systems to provide telemedicine.
services to the maritime sector. MEDI was designed using JAVA and compiled into a webpage application. MEDI relied on TCP/IP protocol to enable functionality on any web browser [17].

Furthermore, MEDI allowed the search and storage of diagnostics images in a medical image database. The telemedicine application also integrated image processing and observation features. Following the implementation and testing of the application, [17] suggests that satellite communication facilities should complement terrestrial networks rather than compete with them or replace them.

In Nigeria, digital health provision through NIGCOMSAT-1 was discussed [18]. NigComSat-1 provided a multipurpose healthcare delivery system, which consisted of a base unit and a telemedicine unit. The telemedicine unit was used for the transmission of 3 and 12 ECGs, vital signs and still images of the patient. The base unit is user-friendly software that receives and sends data to the telemedicine unit for onward storage on the server. Communication between the units was based on TCP/IP protocol.

The telemedicine system was deployed to enhance emergency case handling in ambulances and remote locations, enhance monitoring of intensive care unit patients and provide telemonitoring for patients with chronic ailments. To optimize the performance of the NIGCOMSAT-1 satellite, a PID controller to optimize the position of a dish antenna for distributed telemedicine nodes was designed [19]. The system modelled the time delay when sending and receiving signals from any telemedicine node via the satellite. Afterwards, a PID controller was introduced into the model and it was observed that the time delay reduced to 1.34 seconds as opposed to 86.5 seconds from the previous model. Leveraging this model, the time delay experienced in sending and receiving signals via satellite can be greatly reduced. This reinforces the reliability of telemedicine systems [19].

In India, the use of satellite-based communication for telemedicine was implemented [20]. The project provided telemedicine services to a rural population living in a remote area via the Indian Space Research Organization (ISRO) telemedicine network. The network relied majorly on satellite networks and occasionally on terrestrial networks. Using this model, 15 super specialist hospitals were connected to 45 rural district hospitals. The network architecture was based on a point-to-point connection and point to multi-point connection.

A central server where the patient data can be stored was also developed and configured for a close-user group. So, only authorized personnel can access the server. A website was also designed for communication between hospitals on the network. Telemedicine services provided at each of the hospitals were radiology, cardiology and pathology. The transfer of medical images and data from one node on the network to another was simplified using IP streaming [20].

Power outages posed a great challenge in rural communities where the system was deployed. However, this challenge was mitigated using Uninterrupted Power systems (UPS). Also, the development of an exclusive health satellite (HealthSat) for telemedicine was suggested [20].

The design concept of a mobile telemedicine system was reviewed. The review enlisted a Health Level 7 (HL7) based design method as a standard framework for designing mobile telemedicine systems. Using the HL7 design method would improve the behavior of physicians and the quality of medical and telemedicine service [21]. The HL7 design method also incorporates message requirements, message contents, messaging behavior, and message specifications as characteristics of the framework. [21] highlighted the interference of wireless communication with biomedical instruments as a challenge facing the implementation of mobile telemedicine systems. [21] also suggested the development of a mobile hospital (m-hospital) as an area for further research.

While citing interoperability as a challenge facing the adoption of telemedicine applications, [22] developed an interoperability framework for HL7-based systems. The framework allows stakeholders to perform conformance and interoperability tests for their products based on HL7 standard specifications.

The framework involves checking whether telemedicine applications and products conform to the standards. This test ensures that telemedicine applications can interoperate with other conformant systems [22].

A systemic literature review on telemedicine development in Nigeria investigated the pilot satellite-based telemedicine project carried out by the National Space Research and Development Agency (NASRDA), along with the Nigerian Ministry of Health. The project provided eight (8) telemedicine nodes across the country via the NigComSat-1 satellite. The nodes serve as a point to interface patients with specialists located in Lagos and Abuja [23].

This review discussed the vision for the architecture and financial structure as important project features to note when setting up telemedicine facilities across sub-Saharan Africa (SSA) [23]. The vision and financial design must facilitate the required scope and provide sufficient funds for the project. The review further highlighted the training of personnel and selecting a suitable location as a major index for ensuring the success of any telemedicine project in SSA. The provision of enough doctors to diagnose patients is also another factor that comes into play when hosting telemedicine projects in SSA. This prevents delays in medical attention, especially during emergencies.

VI. APPLICATION OF SATELLITE COMMUNICATIONS IN TELEMEDICINE FOR INTERNALLY DISPLACED PERSONS

A. Overview of IDPs in Nigeria

In 2020, Nigeria recorded the third-highest number (2.7 million) of Internally Displaced Persons (IDPs) in Africa [24]. The number of IDPs in the country rose from one million and seventy-five thousand in 2014 to 2.7 million in 2022 [24].

Accordingly, the newly approved National Policy on Internally Displaced Persons states that the major cause of internal displacement arises from violent ethnic/religious conflict. In some cases, these conflicts have political undertones [25]. In other cases, people are displaced due to flooding, erosion, and oil spillage amongst others. The displacement of persons in Nigeria is further worsened by
extreme poverty, socio-economic imbalance and a high unemployment rate among the youth [25].

Despite the growing number of IDPs in the country, there is no framework for the handling of IDPs nor is there a comprehensive database of IDPs in Nigeria. Although the Federal Government recently launched a National Policy on IDPs, the effects of the policy are yet to be seen and felt. The policy spells out the rights and obligations of IDPs, Government, and Humanitarian bodies.

Specifically, the policy grants IDPs the right to an adequate standard of living, which involves food, water, basic shelter, housing, appropriate clothing, essential medical services and sanitation. It also grants special consideration to children, women, elderly persons and persons living with disabilities [25].

On the flip side, a review of essential medical service provisions for IDPs reveals that 20% of IDPs lack access to any form of healthcare services [28]. While 80% of the IDPs were experiencing one or more forms of acute illness, 87% of deaths in the IDP camps resulted from treatable and preventable illnesses [26]. All statistics available indicate that internally displaced women and children are worst hit by the unavailability of medical health services [26, 27].

Furthermore, Malaria, Malnutrition, Diarrhoea, and respiratory infections were the major physical health problem ravaging the displaced persons. Also, depression and post-traumatic stress disorder were common mental health challenges among IDPs [27].

**C. Results**

The medical outreach carried out at the New Kuchingoro IDP camp was an attempt to explore the potential of telemedicine for digital healthcare delivery to the vulnerable in underserved communities across Nigeria. A total of 317 patients were attended to during the outreach. 116 of the 317 patients were children between ages 0 to 13 who were given deworming medication. 201 patients ranging from ages 0 to 89 received medical attention from doctors through the One2One mobile application. Data elements collected from all the patients include their first names, last names, ages, body temperature, weight, diagnosis, and medication prescribed. For patients above 18, blood pressure and blood glucose levels were also recorded. We used Microsoft Excel for analysis to determine the prevalent health conditions among the patients, the most frequently administered medications, and demographics.

Among the 317 patients who received some form of medical attention, the mean age was 23.6, and a majority of the patients were between 0 to 4 years of age. 52 percent of the patients were female, and 48 percent were male. Table 2, 3 and 4 shows general, gender and age statistics of patients treated respectively.

The average number of patients seen by each doctor per day was 20.1, which is in line with the recommended standard [28]. The outreach lasted 4 hours each day, making a total of 12 hours over three days. The first day was dedicated to deworming 116 children, while the second and thirds days were for medical consultation with 104 and 97 patients attended to respectively. Figure 3, 4, 5, 6 and 7 shows gender count in percentage, gender count per day, age statistics by gender, most frequently occurring illnesses and most frequently administered medications respectively.

Prevalent illnesses in the area included: malaria, musculoskeletal pain, and dyspepsia. Hypertension was also common among the older members of the camp. Paracetamol and Artemisinin-based combination treatments were in high demand, and the quantity available at the outreach was insufficient to cater to all who needed them.
TABLE II. GENERAL STATISTICS

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>Total number of doctors available</td>
<td>5</td>
</tr>
<tr>
<td>Total number of registered patients</td>
<td>317</td>
</tr>
<tr>
<td>Total number of patients who received medical attention</td>
<td>201</td>
</tr>
<tr>
<td>Total number of dewormed children</td>
<td>116</td>
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<tr>
<td>Average number of daily patients per doctor</td>
<td>20.1</td>
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TABLE III. GENDER STATISTICS

<table>
<thead>
<tr>
<th></th>
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<th>Day 2</th>
<th>Day 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>57</td>
<td>24</td>
<td>72</td>
<td>153</td>
</tr>
<tr>
<td>Female</td>
<td>59</td>
<td>80</td>
<td>25</td>
<td>164</td>
</tr>
<tr>
<td>Total</td>
<td>116</td>
<td>104</td>
<td>97</td>
<td>317</td>
</tr>
</tbody>
</table>

Fig. 3. Gender Count and Percentage

Fig. 4. Gender Count Per Day

TABLE IV. AGE STATISTICS BY GENDER

<table>
<thead>
<tr>
<th>Age Category</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>31</td>
<td>33</td>
<td>64</td>
</tr>
<tr>
<td>5-9</td>
<td>18</td>
<td>26</td>
<td>44</td>
</tr>
<tr>
<td>10-14</td>
<td>12</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>15-19</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>20-24</td>
<td>13</td>
<td>17</td>
<td>30</td>
</tr>
<tr>
<td>25-29</td>
<td>14</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>30-34</td>
<td>22</td>
<td>11</td>
<td>33</td>
</tr>
<tr>
<td>35-39</td>
<td>18</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>40-44</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>45-49</td>
<td>7</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>50-54</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>55-59</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>60-64</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>65-69</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>70-74</td>
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</tr>
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<td>75+</td>
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<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>153</td>
<td>164</td>
<td>317</td>
</tr>
</tbody>
</table>

Fig. 5. Age Statistics by Gender
The adoption of telemedicine at the outreach with availability of 5 medical practitioners (online and onsite) made it possible for five patients to be attended to concurrently, thereby alleviating the challenge of long patient waiting times. A major contributor to health challenges at the IDP camp was financial constraints. This was evident in the fact that many inhabitants of the camp were aware of their health conditions, particularly hypertension, STDs, hemorrhoids, and diabetes, but didn’t seek medical attention because they could not afford the cost. Other major contributors to health challenges at the camp, particularly infections, were poor sanitation conditions and inadequate health education. The on-site doctor present during the outreach gave basic health care tips to the inhabitants of the camp to enable the prevention and curb the spread of infections. The drugs administered during the outreach were free, which lessened the financial burden of the patients.

Major challenges faced during the outreach included language barriers and the unavailability of medical testing kits. The drugs available were also insufficient to cater for all the patients. The language barrier challenge was addressed by employing support staff who were fluent in the local language of the area, and served as intermediaries between the doctors on the mobile application and the patients.

Future work will include the addition of translation features to the communication medium of the mobile health application. A comprehensive database of internally displaced persons is also recommended for a needful multi-stakeholder approach for efficient healthcare delivery in such communities and inclusion in health insurance coverage and including other palliative measures. Efforts should also be made to establish permanent telemedicine services in internally displaced camps and underserved communities to lessen the financial burden of hospital visits.

Finally, the Mobile Satellite Kit used in delivering telemedicine at IDP camps can also serve as a mobile emergency response facility that can quickly be deployed to a disaster location to extend emergency healthcare service delivery, and thus is a critical contribution to enhancing the nation's disaster response.

VIII. CONCLUSION

As humanity seeks more ways to provide healthcare services to the multitude who currently have limited access, telemedicine presents a major opportunity for digital healthcare service delivery. Synergizing the capabilities of communication satellites and telemedicine will enable even greater impact, connecting patients and medical personnel from all over the globe. The implementation of satellite-enabled telemedicine strategies will require the cooperation of governments at all levels and international organizations. This might just be the key to accomplishing SDG 3: ensuring healthy lives and promoting wellbeing for all at all ages.

IX. ACKNOWLEDGEMENT

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REFERENCES
