

Review

A Review of IoT Trends and Usage in Developing Economies: The Case of Sub-Saharan Africa

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Abstract: The Internet of Things (IoT) technology has unarguably infiltrated almost all sectors of life the world over. This infiltration has revolutionized the internet, making it possible for heterogeneous objects to be connected to the internet and communicate, thereby showcasing a new form of ICT and giving birth to the concept of smart cities, smart agriculture, smart farming, smart homes, smart healthcare, and what have you. The developed economies have literally grasped the lion's share of this novel paradigm. Meanwhile, developing economies are still dragging their feet towards the adoption and usage of this technology. Sub-Saharan Africa (SSA) is one such geographical area, still at its embryonic stage of IoT adoption and usage. As a consequence, this review article aims at bringing to the limelight the benefits and challenges of adopting IoT in SSA; the areas of application of IoT; and the manner in which IoT technology is exploited in this part of the world. This article will reveal the benefits and challenges of IoT adoption in SSA; how IoT technology is utilized in sectors such as healthcare, agriculture, education, and electricity power management in this developing region of the continent of Africa that lies south of the Sahara.

Keywords: Internet of Things (IoT), Sub-Saharan Africa (SSA)

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Introduction

The Internet of Things (IoT) is a technology that is penetrating the world exponentially [1]. Since its conception in 1999 by Kevin Ashton, the IoT has seen the light of day, has grown to maturity, and has not hesitated to spread its tentacles to almost all sectors of human activity. This proliferation of IoT in many areas of life is practically transforming the world into a smart global village, making it possible to sense the state of objects in their environment and transmit the results through networks and middleware to a remote application for anticipated action by the decision makers. This is realized with the use of smart sensors, smart actuators, gateway devices, and data processors. With this analogy, sectors like healthcare, agriculture, security, traffic control, and education, just to name a few, have been embedded with smart capabilities, making it possible for users to not only remotely receive information, but to

remotely render service. Developed economies have long embraced this technology, wining and dining with it in almost all sectors of human activity. On the other hand, developing economies like Sub-Saharan Africa are still entertaining the handshake process with this technology. Therefore, the purpose of this review article is to disclose the benefits and challenges of IoT adoption and usability in developing economies such as Sub-Saharan Africa, to highlight the sectors where IoT technology is deployed, and also to demonstrate how this region of Africa utilizes IoT technology. This is in a bid to propose the kind of IoT needed by Sub-Saharan Africa; the skills to invest in; and finally, the sectors to invest in IoT technology, so that the adoption and usability of this novel technology should reflect the realities of this part of Africa located south of the Sahara.

The Benefits of IoT adoption and usability in SSA

Agriculture is the future of Africa, but this part of the world cannot develop if agriculture is used as a subsistence activity [11] and without the use of technology [12]. Therefore, employing IoT technology in agriculture will yield a plethora of benefits for SSA as follows: easing access to agricultural services and access to markets for produce; facilitating the management of rural transport for farmers; mitigating agricultural risks with weather forecasts; keeping stock of animals in grazing lands; agro processing factory management; tracking livestock in rural areas so that no animal should get lost; controlling transport logistics and irrigation systems; alleviating poverty and uplifting the standard of living of rural farmers; enabling transporters of agricultural produce to be aware of farmers who require transport; the possibility of running public programmes for agriculture surveillance to enable decision makers to alert agriculture practitioners of potential plant diseases, plant-eating pests and wild fires approaching the farm [10]. Developing economies, such as SSA, are experiencing exponential growth in terms of motorization. Unfortunately, this rapid growth has not triggered the deployment of technologies aimed at enhancing road safety. In this regard, utilizing IoT technologies would go a long way towards mitigating road accidents, thereby ensuring road and highway safety [13]. Environmental monitoring is also of paramount importance for SSA, given that the rate of air pollution, industrial pollution, and noise pollution is immense owing to the rapid rate of population and industrial growth [13]. IoT technologies could be deployed for regularly monitoring the environment, so that the consonance of climate, nature, and civilization could be maintained. Utility management, such as gas, electricity, and trash removal, is another sector where IoT technology will be of great profit for SSA. In order to ensure good water quality for private or public consumption, sensors designed to measure important water parameters are installed at prime locations [14], as cited in [13]. IoT technology has enormous benefits in the education sector, which is fast growing in Africa in general and SSA in particular. Using IoT devices for teaching and learning is an innovative approach to educational management in general and classroom management in particular. The use of IoT technologies for teaching allows teachers to know what students really want to learn and how they want to learn, which is of great benefit to both the student and the faculty. Moreover, the learning process is made easier with the use of IoT technology [15]. Owing to the enormous challenges in the healthcare sector in developing economies like SSA, such as lack of funds, inadequate infrastructure, especially in rural areas, unavailability of essential equipment, inaccessibility to health facilities, shortage of trained medical staff, etc., SSA has embraced IoT technologies as a means of facilitating healthcare [20]. Due to these local challenges highlighted above, the adoption and usability of IoT in SSA will derive many benefits through different monitoring medical devices as highlighted in [20]:

- 1) Blood sugar level tracking through blood glucose monitors;
- 2) Real-time BP readings through the BP monitors;
- 3) Pulmonary ventilation tracked by breathing monitors;
- 4) Cardiac activity tracking through electrocardiogram (ECG) monitors;

- 5) Heart rate monitors are designed to track a patient's number of heart beats per second;
- 6) The unborn baby's heart rate and vital stats are tracked through pregnancy monitors;
- 7) Pulse oximeters track pulse and blood oxygen saturation via fingertips sensors;
- 8) Sleep monitors track and evaluate sleep patterns alongside sleep apnea.

This is an indication that sensors are very valuable when it comes to IoT adoption and usability in SSA owing to their monitoring capabilities.

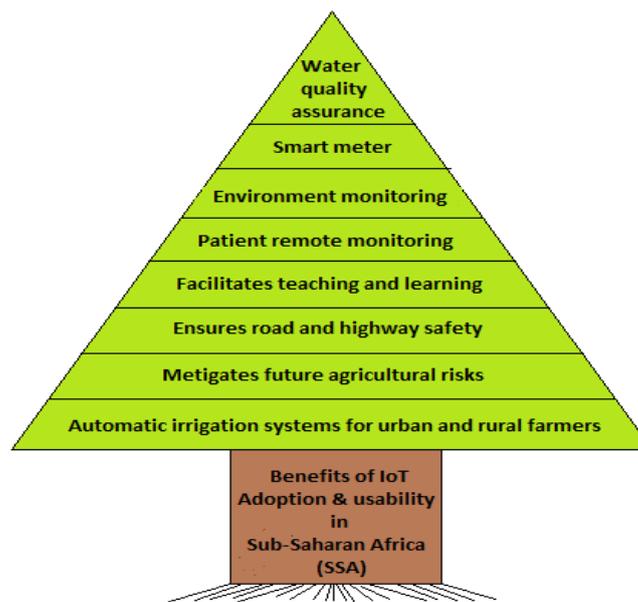


Fig. 1: Benefits of IoT adoption and usability in SSA

The challenges of IoT adoption and usability in SSA

The nectar that IoT technology produces is very sweet, but harvesting this nectar is a nightmare for developing countries, such as Sub-Saharan Africa (SSA). The difficulties that go with it are analogous to the challenges of adopting and using IoT technology. One of the most prominent features of IoT adoption and usability in SSA is the phenomenon of poor internet connectivity [3, 13]. Security of IoT platforms is a cause for concern in SSA owing to a lack of professionals specializing in IoT security [3]. This is more recurrent in developing economies due to vulnerable systems [4]. IoT platform privacy is far-fetched in SSA, given that connected devices can be traced with ease [5]. One of the barriers to IoT adoption and usability in developing economies, such as SSA, includes: 1) access to government structures and services (distance barrier); 2) access to labor markets and wider business (economic barrier); 3) access to education, information, health, training, social services etc. (social barriers faced by rural inhabitants); 4) tracing products throughout the value chain alongside logistics [9] as cited in [10]. Other challenges, according to [13], are classified as technical, device reliability, financial challenges, and security, privacy, and trust issues. The authors further accentuate that technical challenges include internet connectivity issues involving low internet speed; the high cost of internet access; and high power consumption. Moreover, data centers are running on harvested energy and are not able to harvest enough energy, as energy consumption is constantly rising. Also, power resource planning in terms of electricity for developing economies is a complicated dilemma. Again, human resources present a great challenge owing to

the lack of technically knowledgeable personnel. Device reliability is a cause for concern owing to the fact that IoT devices need to be able to run on batteries for a very long time. These devices also need to be robust with the ability to use solar radiation for recharging capabilities like photo-voltaic panels. Another challenge involving the adoption of IoT in SSA is finance [13]. Security, privacy, and trust are the last challenges of IoT adoption in developing economies, discussed by [13]. IoT threats are numerous, ranging from denial of service attacks to physical attacks and identity fabrication.

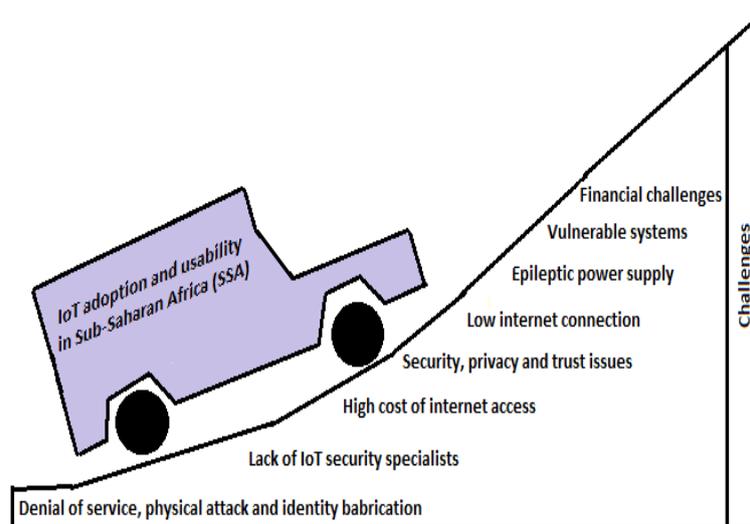


Fig. 2: Challenges of IoT adoption and usability in SSA

The Application of IoT in Healthcare

IoT adoption and usability for healthcare is more advanced in developed economies than in developing ones, such as SSA. From the day a child is born, right up to old age where diseases are chronic, there are immense health management irregularities [13]. People are less concerned about their health situation and do not bother about preserving their medical history. On the contrary, people seek medical assistance when the disease is already in its final stage of destruction [13]. Thus, there is a need for the deployment of intelligent management systems for healthcare in this developing part of the world. IoT could be deployed to enable access to healthcare using sensors and actuators alongside cloud services for data management. One of the most receptive countries south of the Sahara in terms of IoT adoption and usability in healthcare is South Africa [1]. Here, smart meters are deployed by utility service providers in Johannesburg to track energy consumed by healthcare service providers who track outpatients' health [2]. Given that chronic diseases are becoming rampant, many developing economies, such as SSA, are virtually eliminating the traditional hospitalization method where hospital beds are used. Instead, intelligent health monitoring systems are being developed for monitoring the health of patients remotely, which facilitates consultations and prescriptions from doctors, thereby eliminating the risk of contamination [13]. Implementing smart healthcare facilities in SSA will provide connected rooms; easy management of digital medical records; assistant applications for medical staff through smartphones; workflow efficiency management through real-time staff location; patients' location, status, and treatment schedule through patient flow management systems; patient environment regulation such as humidity, temperature, and noise; tagging technology implementation thanks to smart pharmacy inventory management; and the deployment of application consoles to enable patients to track their treatment process in order to communicate with clinicians [21].

The application of IoT in Agriculture

It is worth noting that the population of Sub-Saharan Africa (SSA) greatly relies on agriculture for survival. It is reported that an average of 32% of SSA's GDP is generated thanks to agriculture, a sector that employs more than half of the entire labour force [6]. Unfortunately, it has really become a challenge to ensure food security in this part of Africa, owing to numerous factors such as high population growth, climate change, traditional farming and the reliance on rain-fed farming [7]. Many scholars have proposed several IoT platforms for the agricultural sector suitable for SSA, one of which is the management of irrigation using IoT technology [8]. The role of an irrigation management system automatically controlled by IoT technology is aimed at making predictions as to when crops need water. Based on the data collected, the actuator will initiate the release of water in accordance with the predicted needs. This, without human intervention. This IoT irrigation system uses sensors for monitoring microclimate parameters, water bodies, soil, and plants. For this to be transformed into concrete reality, the scholars in [8] propose a LoRaWAN and fog computing architecture for deploying smart irrigation. This system is made of IoT nodes designed to exchange data with other local fog computing nodes, alongside a remote cloud system to automatically determine the time for irrigating agricultural crops. In their proposal, Nigussie et al. [7] proposed an IoT-based irrigation management system for smallholder farmers in some rural sub-Saharan Africa, such as South Africa, Kenya, and Ethiopia. The system includes sensors that detect the state of the soil (moisture, temperature, nutrients, and pH) and provide data on the water level in the storage, as well as microclimate conditions. The actuators in this system control water flow to the farm using sprinklers, pumps, valves, and water gates. This system employs LoRaWAN for the network connectivity technology. This is because LoRaWAN is a fully open standard solution with no subscription fee, with less costly devices, and it's very suitable for long-range connectivity. Data processing and storing is performed locally, and solar energy is used to ensure constant power availability [7].

The application of IoT in Education

Smart education is another novel concept born from the advent of IoT. This is actually the use of IoT in the educational milieu, where teachers and students interact for the purpose of teaching and learning. IoT technology is used to keep a record of student attendance in an accurate and timely manner using a smart classroom roll call system (SCRCS), which uses IoT architecture [15]. This IoT technology uses RFID tags, which are attached to students' identity cards. These identity cards can collectively be read by the smart classroom caller system (SCRCS) installed in every classroom. A light-emitting diode (LED) is used to display the total attendance of each student, a record of which is also kept at the academic office for subsequent purposes. Another IoT technology for smart classrooms is the web-based attendance system, which uses Near Field Communication (NFC), in which the student taps a matric card against the NFC smart phone and the attendance is automatically saved on a local server [15]. Here, Android smart phones are used by both teachers and students to check attendance [16], as cited in [15]. The adoption and usability of IoT in education will enable students to directly connect with their teachers and receive reports and instructions even if they aren't physically in class [22]. Therefore, students who are unavoidably absent because of sickness or any unforeseen circumstance would still connect with the teachers and either get lessons or submit their homework from home.

The application of IoT in Electric Power Management

The implementation of IoT technologies in electric power management has yielded positive results in SSA. For instance, in Tanzania, the stability and reliability of transmission lines has greatly improved with the use of IoT technologies [17]. This is achieved with the installation of wireless sensors through towers and transmission lines to

automatically sense and monitor different adverse conditions that usually occur in these electric power transmission lines. IoT technologies have also been implemented in the customer domain, allowing home appliances to be embedded with communication and computational abilities consisting of a sensor, actuator, server, and visualization interface aimed at leveraging home appliances [17]. These smart meters, designed for poor and rural areas in Tanzania, use Arduino and Raspberry Pi platforms linked via a network running on IoT based protocols such as MQTT and CoAP [17]. In Cameroon, the electricity power supply company (ENEO) implemented smart prepaid electricity meters which enable customers on the one hand to manage their electricity consumption and ENEO on the other hand to: 1) receive payment from customers via remote payment platforms, such as Orange Money, MTN mobile money, UBA, etc.; 2) remotely disconnect and connect electricity supply to customers; 3) put an end to physical electricity bills from ENEO agents every month; 4) put an end to physical interaction between customers and ENEO staff [18]. These smart meters are connected to the Metering Management System (MMS) for remotely reading meter consumption [19]. The Customer Interface Unit (CIU), also called the box, is the communication interface directly connected to the smart meters through which customers monitor their electricity power consumption so as to recharge the smart meter [20]. It's worth noting that electricity supply will be cut off whenever the customer's credit runs out, and this will be visible on the screen of the customer's CIU, accompanied by an audible alarm. However, the customer has the possibility of borrowing 10 kWh by using the code 811 if immediate recharge is impossible [20]. The deployment of these smart meters has greatly improved the relationship between customers and Eneo.

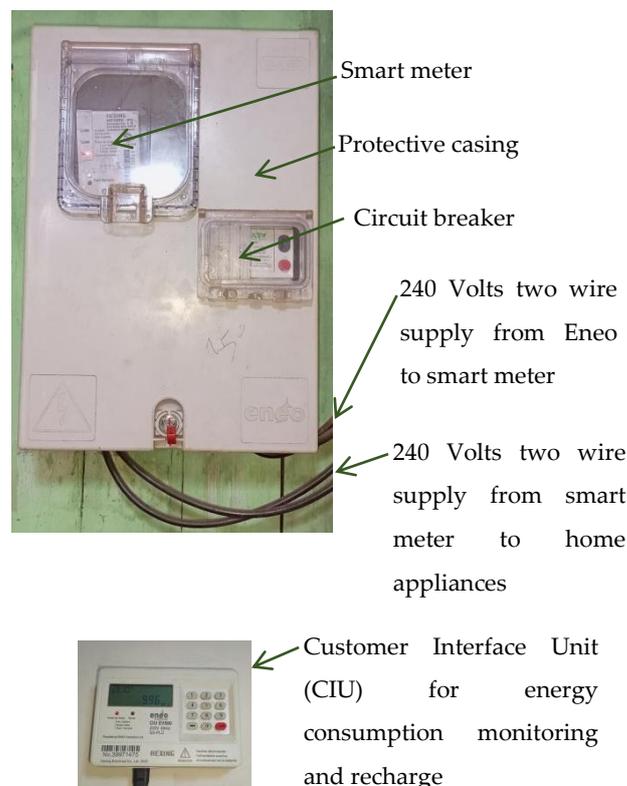


Fig. 3: Smart prepaid meter in Cameroon

Discussion

The purpose of this review article was to disclose the benefits and challenges of IoT adoption and usability in developing economies such as Sub-Saharan Africa; to highlight the sectors where IoT technology is deployed; and also to demonstrate how this region of Africa utilizes IoT technology, so as to propose the most suitable IoT technology for SSA; the skills to invest in; and the sectors to invest in IoT technology in, so that the adoption and usability of this technology should reflect the realities of SSA. Literature revealed that the most prominent benefit of IoT adoption and usability in SSA is remote monitoring and control, while low internet bandwidth tops the chart when it comes to adoption challenges. SSA has embraced IoT technologies in the following sectors: healthcare, agriculture, education, electric power management, and traffic control. Literature reveals that one of the most urgent sectors that require IoT technology is healthcare. This is because of the many challenges faced by the healthcare sector in Africa, such as lack of access to healthcare; poor technological advancement; poor supervision; poverty; weak health information systems; lack of political will; health system corruption; poor maintenance of healthcare infrastructure; inadequate human resources; weak health systems; poor administration and leadership; poor resource allocation to healthcare; lack of good resource management; migration of health personnel; poor regulation, weak training and education etc. [23]. The deployment of IoT technology for healthcare in SSA will enable patients to be monitored, tracked and treated remotely without any physical contact with the doctors. This will greatly reduce expenditure and the risks of accidents, especially with the poor state of roads, notoriously known in SSA. Patients' records will also be stored automatically in a central database for future reference. The phenomenon of brain drain will be addressed, as doctors in geographically distant areas will be accessible. It is necessary to invest in IoT skills such as sensor knowledge, machine learning and artificial intelligence, cloud computing, big data, JavaScript, and Python. IoT is a new paradigm that is still penetrating Africa in general and Sub-Saharan Africa in particular. The newness of this technology renders systems vulnerable to external and internal attacks. So, there is also a dying need for professionals specializing in IoT security. Internet connection availability is of paramount importance to IoT, given that it's the medium through which IoT transmits data. In this regard, internet connectivity should be facilitated to enable individuals and organizations to deploy and manage IoT platforms with flexibility.

Conclusion

Although literature reveals that SSA is dragging its feet as far as adopting and using IoT technology is concerned, some SSA countries, such as South Africa, Kenya, Tanzania, Cameroon, and Nigeria, just to name a few, are making efforts to deviate from this status quo. This can be felt in sectors such as healthcare, agriculture, education, and electric power management. Sub-Saharan Africa is moving slowly but surely.

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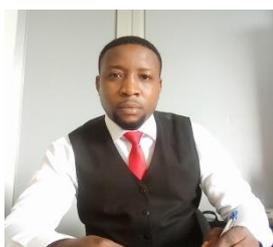
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