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IoT AS A CATALYST FOR TECHNO INNOVATION IN AFRICA

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ABSTRACT

The Internet of Things (IoT) is among the significant disruptive technologies that are gaining interest in Africa because of their potential to create new or transform existing products and services. IoT comprises of networks of sensors and interconnected things which make it possible for the collection of a vast array of information on our environments, and this is nowadays achievable at a higher level of distinguishable detail in collected information. This paper explores how IoT can be leveraged for techno innovations in Africa. The paper aims at answering the following questions: 1) What technologies and applications are enabled by IoT 2) How can IoT be leveraged for techno-innovation in Africa and 3) What are the challenges in leveraging IoT for techno-innovation in Africa? The study is carried out through literature review. Various sources of literature that were reviewed include scientific research papers in journals and conference proceedings, and from online journals and reports. This paper takes an in-depth look at the many possibilities for techno innovation and economy offered by IoT applications as well as the challenges that these IoT applications face

Keywords: IoT, Techno Innovation, Challenges

INTRODUCTION

Science, Technology, and Innovation (STI) are recognized by the African Union Agenda 2063 for their potential to provide tools that are multi-functional as well as other enablers necessary for the achievement of development goals of Africa. The African Union Commission states that economic growth and transformation of Africa requires a continuous investment in new technologies and innovations in ICTs, agriculture, clean energy, education, and health (African Union Commission, 2014). Africa can be considered an early adopter rather than a follower of technology in some instances as indicated by the continent having the highest mobile growth rate in the world. Technological innovations on the continent are transforming many of the products in existence that are deemed to be complicated to use or are expensive and simplifying them for ease of use, and making them be more affordable and accessible to more

people in society. A good example is the mobile money platform now being used in Kenya and its neighbors in East African (Ojomo, 2016). The digital revolution in Africa is a consequence of emerging and disruptive technologies, among them the Internet of Things (IoT), Mobile technologies and sensor technologies, Smartphones, deep learning/ machine learning, robotics and blockchain technologies that underpin this technological revolution, as well as enhancing affordability and accessibility (PWC, 2016).

According to PWC (2016), disruptive innovations anchored on emergent technologies such as IoT are already transforming Africa's economic potential for economic growth by creating new markets segments and new consumer choices or preferences. Broadband internet, in particular, has been growing rapidly in Africa with wireless broadband internet access experiencing growth that is faster than the fixed broadband as a consequence of rapid advancement in mobile phone technologies. The broadband services are today being offered by nearly all mobile service providers on the continent for prepaid and post-paid subscribers. A report by the United Nations Economic Commission for Africa (2014) indicates that in recent years the capacity and speed of broadband internet has been on an increasing trend while the costs are generally high but are beginning to decrease gradually. These factors are leading to the growth of the internet on the continent, as well as the technologies that depend on or are spawned by the internet such as IoT, cloud computing, block chains etc, and are increasingly being taken up in Africa. For IoT, its future in Africa is promising and it is increasingly becoming relevant to various segments of society because of the rapid growth in use of mobile devices on the continent, embedded and ubiquitous communication, cloud computing and data analytics (Patel & Patel, 2016). IoT is considered a representation of the Internet evolution and is important because of the immense ability it gives us to be able to gather, analyze and distribute data and information or knowledge (Evans, 2011). In spite of IoT's potential to spur techno innovation and economic growth in Africa, several challenges and barriers still exist. African initiatives in IoT tend to focus mainly on the technical implementation of internet technologies, with little focus on how IoT applications can be supported to spur techno innovations for the benefit of society. There is a knowledge gap within research studies as to how IoT applications could be supported on the continent to contribute to techno innovations in Africa, and therefore a better level of understanding of the technologies is necessary to spur techno innovations. Masinde, (2014) observes that IoT adoption in Africa is achievable but chances of success can be higher when realities such as the prevalence of African indigenous knowledge on weather, unreliable communication, low-end mobile phone handsets etc can be innovatively incorporated into an African homegrown flavor of IoT. This paper synthesizes IoT applications, areas IoT can be adopted and the challenges with a view to establishing their potential for techno-innovation in Africa.

METHODOLOGY

The study is carried out through a literature review and provides a narrative overview of IoT by synthesizing the findings of literature retrieved from searches of scientific research papers in journals and conference proceedings and industry reports. The search was broadened by Google Scholar and other online journals where the following keywords were used as search criteria, 'Internet of Things', 'Techno-innovation' and 'Africa'. The narrative literature review aims at summarizing different studies from which conclusions can be drawn into a holistic interpretation of existing theories, models and the reviewers' views (Ferrari, 2015).

LITERATURE REVIEW

IoT provides an ecosystem for application development that is characterized by a distributed and intelligent network comprising smart devices. It, therefore, has the potential to spur techno innovations for fundamental services in areas such as education, utilities and service delivery, transportation, security, and healthcare among others. There is great potential for IoT data to have a huge impact in our daily lives because of the enormous advantages that can be realized from IoT data, especially when proper tools are used for data mining and data analytics in the various domains that IoT is applicable. According to PWC (2016), there is an increase in the number of 4G and 5G mobile connections on the continent, and this is further leading to an increase in IOT opportunities, by turning many devices ranging from a toothbrush, Television sets, smartphones to CCTV cameras into constantly monitoring and communicating smart devices. This paper uses the term Internet of Things (IoT) to refer to the use of intelligently connected smart devices and systems to exploit opportunities provided by data gathered by embedded sensors and actuators in the smart devices and other physical objects (GSM Association, 2014). The goal of IoT is to enable things to be connected at any time and place, and with anything using any network and service, and is therefore viewed as an ecosystem of a distributed network that connects these things ranging from smart devices to other physical objects which are capable of sensing and collecting data in their environment and communicating with each other. Patel & Patel (2016) observed that IoT connects things with the internet through information sensing devices based on stipulated protocols in order to conduct information exchange and to achieve positioning, tracing, smart recognition, monitoring, and administration. The things or devices that are connected to the IoT include smartphones, tablets, sensors in physical objects and other wearable electronic devices. With proper tools for data analytics, the data generated by these devices can be analyzed in order to reveal valid, new and previously unknown information, and also help in generating suggestions of possible actions that may lead to the transformation of existing or creating of new products and services through cost savings and increase in efficiency. There two key factors that are necessary for the growth of IoT in Africa (GSM Association, 2014), and these are 1) reduction of prices and standardization of key IoT hardware and software components, and 2) the extent to which IoT is integrated with Big Data and Analytics since this may lead to new insights from which companies can exploit to improve efficiencies and

increase revenues. Cisco's Internet Business Solutions Group (IBSG) has predicted that by 2020, there will be approximately 50 billion devices actively connected to the internet, and these will generate more data and lead to more information exchange. This forecast indicates the future is going to be good for businesses, the internet service providers and mobile operators in particular because their charges are pegged on data rates of data transmissions. According to Saidu *et al* (2015), there are expectations that billions of devices will fill the internet superhighway. These devices together with other embeddable devices will have to be produced by hardware manufacturers, meaning that the market for hardware manufacturers of businesses connectivity devices and other physical objects with sensors is going to thrive in the future as a consequence of the growth of IoT.

IoT TECHNOLOGIES

The IoT architecture comprises of various technologies that relate to each other and serves to illustrate the modularity, configurations, and scalability of IoT applications as is illustrated in Figure 1 below. This architecture is made up of the following layers, the sensor layer, the gateway and network layer, the management service layer, and applications layer where each layer serves a specific purpose in the architecture. The use of smartphones and sensor technology is being elevated through connections of sensors and the subsequent capture of data at high levels of granularity for analysis and action. Among the fastest-growing segments of IoT are the wearable technologies comprising of smart devices equipped with microchips, sensors, and wireless communications capabilities and are networked. These wearable technologies will likely have a widespread societal influence in the future. The sensors embedded in the physical objects on the IoT network use various types of technologies for connection among the Radio Frequency Identification (RFID), Wi-Fi, Bluetooth, ZigBee, GSM, GPRS, 3G,4G and LTE (Ndubuaku & Okereafor, 2015). Thierer (2015) holds the view that wearable technologies and IoT will disrupt the existing social, economic, cultural and legal norms.

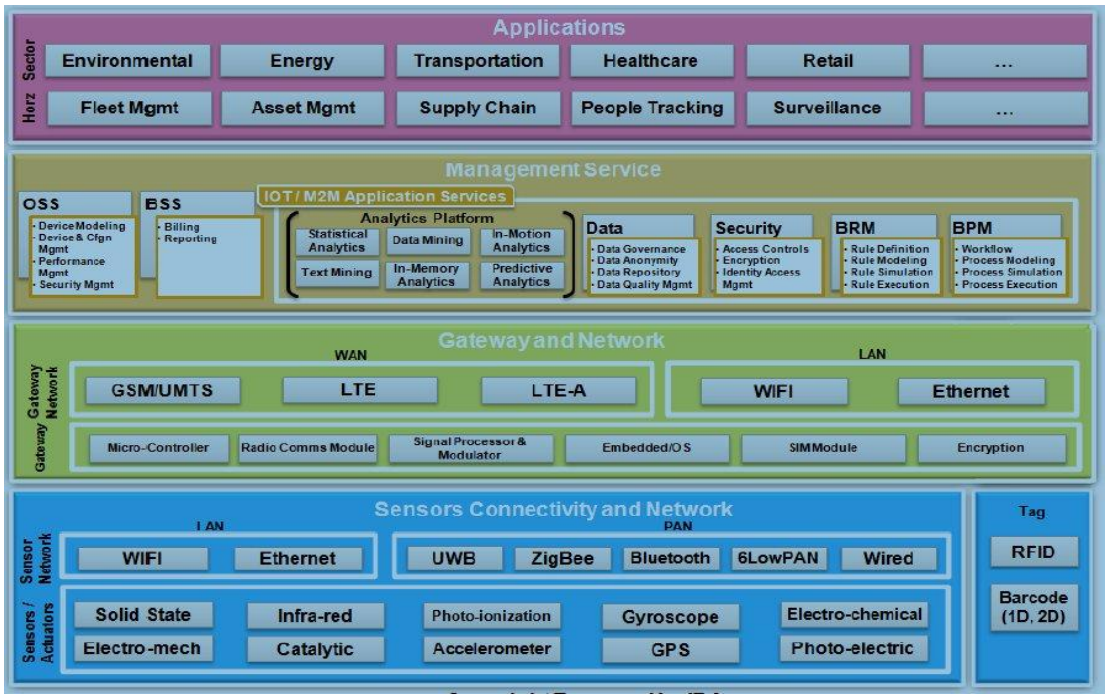

Figure 1: IoT Architecture (Adapted from Ndubuaku & Okereafor, 2015)

The implementation of IoT is done using a number of existing network technologies, and Andrea *et al* (2015) highlighted the following three 1) Radio Frequency Identification (RFID) technology that uses radio frequencies in the design of microchips for transmitting data in wireless communications. RFID uses either passive or active tags or labels attached to objects and acts as electronic barcodes for automatic identification. Passive RFID tags are non-battery powered and use the power of the reader's signal to communicate the ID to the RFID reader while active RFID tags can instantiate communication since they are battery powered. 2) Wireless Sensor Networks (WSN), which are made up of distributed heterogeneous small devices that are low cost, use low power and have sensors to monitor conditions in their physical environment. Such WSN systems have gateways to provide wireless connectivity to the geographically distributed network. 3) Cloud computing which enables ubiquitous deployment of sensor technologies to enable smart monitoring and actuation using the smart devices as well as the storage and subsequent processing and intelligent use of the data collected by these sensors

APPLICATIONS ENABLED BY IOT

IoT has the potential to create new products and services, new business models, new technologies and new roles for IT. IoT applications have a great potential to transform Africa since they have the capability of facilitating the alleviation of the many challenges on the continent through performance enhancement in many sectors (Al-Isma'ili *et al*, 2017). IoT applications refer to solutions using IoT technologies to improve products and services including areas of industrial manufacturing processes and in offering optimized infrastructure and reducing operational costs (Fantana, *et al*., 2013). IoT has the potential, not only to transform the quality of products and services but also individuals' quality of life. This is because, through its distributed network of smart devices, wearable's and other physical objects fitted with sensors, IoT provides an ecosystem with potential for application development enabling techno innovations in many areas including transportation, logistics, security, utilities, education, healthcare and agriculture (GSM Association, 2014). However, success of such IoT techno innovations in developing value-added capabilities for the above-mentioned areas requires a broad approach that takes into consideration expertise in sensing technologies, hardware, distributed and networked systems, deep learning, machine learning, human-computer interaction, security, data analytics and privacy (Alur, *et al*., 2015). At the industry level, the growth of IoT, and the increase in the use of networked smart devices will no doubt unlock opportunities for boosting productivity for enterprises and in providing life-enhancing services for consumers (GSM

Association, 2014). There are many IoT applications that are addressing societal needs that are emerging but due to rapid advancements in the various technologies supporting IoT, it is not usually easy for application developers to envisage all potential IoT applications required by potential users due to the diverse needs of these users. A number of IoT service providers have begun operations in Africa. Global ICT solutions provider Huawei for instance first entered Africa in 1998, and demand for its IoT platform has continued to grow in South Africa, Nigeria, and Kenya. The IoT technology in Africa is playing a significant role in improving the living standards of millions of people with significant signs of its worth being seen in areas such as agriculture, animal conservation, and utilities as well as enabling companies to detect and repair equipment faults promptly repairs. According to Al-Isma'ili *et al* (2017), IoT can help in agriculture by enabling people to produce high-yield crops with less effort and to provide them with reliable tools for monitoring and controlling the use of water resources. IoT can also be utilized in the healthcare sector to monitor patients' wellbeing, and can also play a significant role in improving physical security in Africa since crime rates across the continent are relatively high.

Coetzee & Eksteen (2011) states that there a number of applications suitable for many situations on the African continent and lists them as follows: 1) Food security: IoT has the capability for offering tools for measuring and responding appropriately to issues affecting food security. Such issues include droughts, floods, pests, appropriate knowledge of farming methods in different circumstances, all of which have a significant implication for food security on the continent. IoT interventions may be deployed in the form of large-scale fusion of remotely sensed information mixed with sensors and other ICTs to relay timely information to farmers on the attention needed on their farm. A good example is where IoT is used to monitor on a continuous basis the fertilizers and pesticides used on export-bound products with the objective of enabling farmers to have their products certified for export markets in a cost-effective manner. 2) Natural disasters: The occurrence of natural disasters such as landslides, floods and earthquakes can be predicted in time for information to be relayed to residents to take appropriate safety actions, through use of IoT technologies comprising of remote sensors and simulation. In such cases, the remotely sensed data may be used in combination with simulation tools to provide real-time information to enable appropriate action s to be undertaken as necessary. 3) Water: Through IoT technologies, networks of sensors may be combined with relevant simulation activities in order to monitor long-term water interventions such as catchment area management, and also to alert users of any problems that may occur in water streams. According to (Liquid Telecom, 2017), IoT can also play an important role in the maintenance of equipment used to supply water and therefore help rural communities across Africa get supplies of clean water

IoT applications are finding their use in many sectors across the continent. For example, start-up Sweet Sense installed about 200 sensors in rural water pumps in Rwanda in 2014. The sensors helped dramatically

reduce the number of pumps broken in an area at any given time; as well reduce the repair interval at pumps. In South Africa, IoT is being used for limiting the loadings on smart meters and helps in warning residents of imminent outages. These smart meters are fitted with sensors to monitor power usage in households in real-time such that residents receive an SMS asking them to reduce power usage whenever they use too much electricity (Liquid Telecom, 2017). Similarly connected cameras have been used in Africa's game reserves and national parks for years, capturing the best night shots of animals at the watering hole, alerting safari operators on the location of that elusive lion and providing new information on animals' movements and behaviors throughout the seasons. According to Masinde, 2014), security is a big problem in some countries such as South Africa, where houses have alarm systems, a situation that has driven demand for smart home applications focused on improving security, and also takes on a more important role with connected cars with existence of a strong demand to more accurately monitor cars in order to prevent theft. Security service providers can collect data location and behavior on their backend IoT platform, which provides service analysis that, can be used by the car industry. IoT can also be a huge help in addressing the challenges facing Africa's utility providers. Smart meters are gaining popularity and traction globally, and the technology has a compelling business case across the continent. Smart meters give both businesses and consumer a more accurate overview of usage patterns, enabling more accurate billing and improved energy efficiency. With smart metering adoption rates growing globally, the technology is attracting increasing attention from investors (Liquid Telecom, 2017). The biggest benefit of IoT in the energy space is the ability to perform monitoring and maintenance remotely, making it a very attractive opportunity for energy providers, which typically spend large amounts of money on upkeep of rural assets.

IoT FOR TECHNO INNOVATION

IoT is one of the ICTs underpinning techno innovations in Africa and is enabling improvements in products and services in terms of improved efficiencies and competitiveness in many sectors. Technology innovation is defined as new technology introduced or created. Masinde (2014) states that technology innovation should ideally be followed by the adoption or adaptation of that technology innovation otherwise the efforts of that innovation will remain futile. Innovative IoT applications in combination with cloud computing and big data and analytics promise to offer opportunities for new business or extension of existing ones for the hyper-connected society despite the strong barriers it faces in terms of security risks, privacy concerns and resistance to changes particularly in organizations. The focus of IoT is to entrench connectivity and intelligence in devices and physical objects in order to facilitate the collection of vast volumes of data in real time and therefore offers numerous opportunities for innovative products and services to be offered using smart devices, machines, and other physical objects. The vast volumes of data when analyzed present new levels of information and intelligence for businesses, which they can use for techno-innovations and to

drive efficiencies, reinvent business models and transform the customer experience. IoT, therefore, has the potential to offer a range of new and innovative products and services and solutions to problems facing individuals across the continent. In doing so, it helps to address some of the existing challenges faced by people in Africa, including the high levels poverty and the need for the underserved populations to have access to basic services (Ndubuaku & Okereafor, 2015).

Ubiquitous Internet connectivity of smart devices and sensors embedded in physical objects presents us with innumerable opportunities to not only to create innovative products and services but also to reduce operational costs and increase revenues for organizations (Shaw, 2016; Mourtou *et al*, 2016). Organizations can, therefore, increase operational efficiencies and increase their revenues, as a result, their research and development of IoT and investments in ICT. Masinde (2014), asserts that innovative products and services are emerging thanks to the exponential growth of the internet with ubiquitous connections of smart devices, low-cost sensor technologies, wireless networks, pervasive connectivity, big data, availability of cheap microprocessors, shrinking devices, and fast cellular connections. These innovative products and services have changed people's perceptions and expectations of IoT and what the internet can do for them. The traditional experience of wearing a watch for instance may be transformed to provide useful and actionable insights from the data collected when connectivity is combined with data aggregation and analysis because data obtained from a smartwatch could, for example, be streamed to an individual's healthcare provider or personal trainer using IoT applications that can operate without any user intervention for the necessary action. IoT has a great potential to revolutionize the agricultural sector because of the valuable data sets that it can help produce in order to help farmers make informed farming decisions (Liquid Telecom, 2017) by relying on new technologies comprising of wireless sensors to track the growth of crops, soil moisture levels, and water tank levels. There is also potential for IoT to maximize efficiencies in the healthcare provision in Africa since healthcare resources are usually thinly stretched by providing a platform to enable healthcare providers to continuously and remotely monitor patient's vital signs in a reliable and undisturbed manner through wearable devices which can monitor patients attributes such as pulse, respiration rate, body temperature, sleep patterns and movement. Such wearable devices can send the collected data to cloud applications where algorithms can create actionable insights for medical practitioners.

IoT innovations in healthcare can, therefore, lead to better healthcare for patients, efficiency in sourcing medical products for healthcare providers, and may ultimately lead to better health services and efficient use of resources in the health sectors.

More importantly, IoT can also be used to improve road safety on a continent with the highest rate of road traffic fatalities in the world by enabling monitoring vehicular traffic for example speed limits observations.

Much further down the line, connected car technologies are likely to emerge more on the market, bringing with them innovations such as self-parking and emergency braking assist. IoT innovations can also offer viable solutions in many areas. For example, effective drought response requires precise real-time information to proactively manage water costs. Sensors and monitoring systems can help farmers to measure moisture and find leaks swiftly (Prinsloo & James, 2015). IoT innovations in agriculture might also help in other ways, such as integrating farmers in markets and services where access has previously been limited (Prinsloo & James, 2015). If harnessed properly IoT innovations can offer opportunities for dealing with the challenge of youth unemployment, especially since most African countries comprise of growing economies which provide fertile ground for innovation and risk-taking by Governments and citizens (United Nations Economic Commission for Africa, 2014). IoT components and the business viability they provide can be used to achieve considerable cost reductions by improving utilization of resources, enhancing process efficiency and boosting productivity. Open and integrated IoT environments hold the promise of being among the tools for achieving the United Nations Sustainable Development Goal, and have the potential to enhance the productivity and competitiveness of African SMEs (Rose *et al*, 2015; Campolargo, 2013).

CHALLENGES

Africa experiences low levels of funding for research and innovation projects. Ramos (2014) states that limited access to funds for research and innovation is a common problem for many countries in Africa. In contrast developing countries have higher levels of funding for research and innovation, for instance, the UK Government in an effort to accommodate new and emerging technological innovation allocated £40,000,000 in their 2015 budget towards research into the Internet of Things (Mourtou et al, 2016). This level of funding for technological innovations is yet to be achieved by African nations. Mugabe (2011) observed that African countries tend not engage in the creation of technology and are generally not significant sources of technological innovations. This implies that many African countries are technologically marginalized with most countries, especially in the sub Sahara being ranked very low in terms of technology research and innovative capacities. Africa has therefore not kept pace with global community in terms of technology advancements and continues to lag behind in nearly all technology spheres. In the ICTs for instance, only 7% of Africa's households are on the Internet while the world's average figure stands at 41% (Masinde, 2014). However, there is hope for Africa especially since evidence exists to suggest that the continent can be on the forefront in some technology innovations e.g. mobile money platform M-Pesa. Indeed given the benefits of IoT, there is sufficient motivation for Africa to work towards overcoming challenges that may be existing since they can be overcome (Evans, 2011).

Although efforts to establish innovation hubs in Africa have been established to create opportunities for start-up businesses or innovators to partner with established businesses in efforts to create ecosystems of

creativity and enterprise, these efforts are hampered by lack of necessary infrastructures such as internet, electricity, technical expertise, roads, and inadequate regulatory support. There are several barriers that threaten the growth of IoT in Africa (GSM Association, 2014). The leading three are 1) The slow deployment of IPv6 addresses after reports that IPv4 addresses had been depleted in 2010. This can potentially slow down the progression of IoT in Africa since the billions of new devices or things requiring connection to the internet must have unique IP addresses. IPv6 addresses offer improved security features and have auto-configuration capabilities that make the network management easier. 2) Sensor energy (Power for sensors). Self-sustaining sensors are essential for IoT applications to work in Africa due to the scarcity of electricity especially rural areas, and therefore there is a need for sensors that generate electricity from environmental elements such as light, solar, vibrations, and airflow. 3) Lack of agreement on standards. There is a need for more to be done to solve standardization issues relating to IoT components in the areas of architecture, communications, security, and privacy. Davies (2015) observes that there is a need to develop technical standards to support IoT. IEEE is working to solve some of the architectural and communication challenges by offering solutions for routing IPv6 packets across different network types. If devices from different manufacturers do not use the same standards, interoperability becomes difficult requiring extra resources such as gateways to facilitate interoperability between standards. According to Davies (2015), encouraging open standards and interoperability will spur innovations, competitiveness and broaden choices for IoT consumers. For example, if a company finds itself favored by certain standards and is able to control a market segment such as the access to and acquisition of specific data which it then uses to come up with innovative solutions or services may dominate a market and create barriers for smaller entrepreneurs that those standards are not favorable to.

IoT is considered as being more than a technology; but rather as an ecosystem of products and services at the heart of which lies connectivity (Liquid Telecom, 2017). There is therefore a need for a multifaceted approach that transcends technology, and takes into account concerns of data security, privacy and regulatory issues when it comes to formulating strategies to make IoT practical in Africa and to spur its adoption insufficient levels to offer support for innovative products and services (Alur, *et al*., 2015). Although IoT continues to experience exponential growth in Africa, it suffers from security and privacy vulnerabilities, due to the decentralized topology of the networks and the resource constraints of the devices In IoT since the conventional security and privacy approaches used in distributed systems are inapplicable (Dorri et al, 2016). As a consequence of the requirement for novel security and privacy approaches which have not been fully addressed, many IoT devices in use today are not secured inadequately leaving users and organizations vulnerable to attacks. Numerous security vulnerabilities have been identified in many of the IoT devices such as smart locks. The intrinsic features of IoT devices may also contribute to their security

and privacy challenges, and these include multiple attack surfaces, lack of central control and generally the heterogeneity of the device resources contribute to the challenges

The use of smart devices and embedded sensors in physical objects in the IoT ecosystem has led to the need for new legal and regulatory items addressing the use of the internet and a re-evaluation of the adequacy of the existing ones. Rose *et al* (2015) noted that the rapid rate of technological changes in IoT applications frequently outpaces the ability of the associated legal, regulatory and policy structures in Africa to keep up the pace or adapt. Many jurisdictions on the continent do not have data protection laws, and data collected by IoT devices may in some cases be susceptible to misuse and may be used to cause harm to or discriminate IoT users. There are also issues relating to cross-border data flows that may arise when IoT devices collect data in one jurisdiction and transmit it for processing in another jurisdiction with different data protection laws. Additional legal issues surrounding IoT applications that often come to the fore include the conflict between law enforcement surveillance and civil rights, lack of clear data retention and destruction policies, and issues relating to legal liability for unintended uses or how security breaches and privacy lapses may be handled legally. Dorri *et al* (2016) pointed out that the increasing number of IoT applications will push the limits of networks and stress the performance capabilities of the networks that are in existence today and will pose challenges in the areas of cloud computing, data analytics and geographic information system based visualizations.

CONCLUSIONS AND RECOMMENDATIONS

This study aimed at providing a better understanding of the IoT applications and their potential to spur techno innovations in Africa. The study also highlighted the challenges faced in using these technologies as well as the benefits of IoT for the African continent. The future of IoT technologies in Africa is bright and therefore African governments need to address existing challenges so that these disruptive technologies can be harnessed to provide cost reductions and efficiencies for the various products and services on the continent. The disruptive nature of IoT requires efforts be made in order to establish standards that will help in the areas of interoperability, interfaces, trust, security, and privacy, as well as to help in integration of various IoT applications. In order to realize the potential of IoT, this study recommends that researchers, governments, organizations and other stakeholders find ways of dealing with shortcomings in standards related to IoT technologies, data and infrastructure management capabilities and skills. African Governments should be on the forefront by playing a key role in providing the necessary statutory and regulatory support and development of infrastructures such as telecommunications and electrical power in order to spur IoT innovations.

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