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Review Article

Internet of Things (IoT): The Technology, Architecture and Applications – Prospects in Nigeria

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Abstract: There is presently a technological revolution in the world and our way of life has started changing at a fast forward pace. Thanks to Information and Communication Technology (ICT) and the Internet. The Internet is a global inter-connection of systems over a Wide Area Network (WAN). The Things in the Internet of Things could be described as intelligent objects capable of connecting to the Internet while the objects are software or electronically embedded. Internet of Things (IOT) is an enhanced technology that allows connectivity between physical objects wirelessly through the internet and enables information sharing with other networks for the purpose of processing such for the users; an interaction between the physical and digital worlds through a loose assemblage of sensors and actuators without human intervention. IoT is the new platform for network communication. Infrastructure, Communication, Interfaces, Protocols and standard are some of the fundamental issues involve in the development of Internet of Things. IoT applications are developed software embedded with objects such as the sensors to drive the Air-Conditioners in homes, Cars, home and street lightening systems, Micro waves transportation and the automotive industries. This paper discusses the IoT as one of the emerging concepts of the ICT revolution - the technology, architecture and applications. Finally, a brief elicitation of the benefits of this great concept (IoT) and its applications to Nigeria and Nigerians is presented.

Keywords: IoT, Network, Technology, Devices, Sensors

1. Introduction

Computer Networking and Inter Network systems have turned the whole world into a single global village with the consequential evolution of ubiquitous systems. Internet of Things (IoT) is the newest of the latest technology in the area of ever evolving Information and Communication Technology (ICT). The Internet of Things (IoT) is a technology that consists of objects equipped with sensors, actuators, and processors enabled to communicate with each other [1]. These devices are able to communicate and interact over the internet with other related devices because of being embedded with the required technology and also capable of being remotely controlled and monitored. According to Li *et al.*, "IOT is not just a concept but can prove to be a revolution in advancing technology to change the lifestyles of humans altogether" [2].

2. Scope of This Study

This paper is purely theoretical, research and qualitative. An assessment of the Internet of Things technology was made by evaluating the IOT through the following components; the Hardware, Architecture, Connectivity and Applications. The benefits of its application to Nigeria and her citizens were also evaluated and reported.

3. Literature Review

Evans and Taylor in describe the Internet as one of the most important developments of mankind and IoT will represent the next evolution of the Internet with its capability of gathering, analyzing and distributing the data, IoT consists in the connection between the Internet and a range of devices and sensors [3, 4]. IoT, can be divided into six elements that help us

understand its real meaning and functionality, i.e, identification, sensing, communication, computation, services and semantics [5]. Gloria *et al.,* stated in their work that IoT projects have the ability to do more than just connect the device to the Internet, they can be a big part of improving the efficiency or even adding new features such as Artificial Intelligence, transforming every common objects into connected one [4]. Essentially, IoT consists of four fundamental components which are: a. Sensors/Devices b. Connectivity c. Data Processing and d. User Interface (section 4.1) [1].

In the development and implementation of an IoT architecture, Zhong emphasized that a gateway is required to provide the connectivity for the user to the network, allowing the conversion of data between the short distance communication protocols to the traditional communication network and is supposed to support different types of sensor nodes, multiple communication protocols, both wireless or wired, and provide a set of unified information for the application or user, making these only responsible for data processing [6]. Mehmood *et al.,* defined an internet of things (IoT) platform as a multi-layer technology that enables automation of connected devices within IoT and serve as a middle-ware solution which act as supporting software that is able to connect different hardware devices, access points, and networks to other parts of the value chain [7].

4. Review of Related Work

4.1. The IoT Technology

The Technology of IoT majorly comprises of the task of making objects (Physical) such as, Fridges, Phones, Doors, Cars, Trucks, Heaters, Cookers, Lamps etc. establish connectivity with other types of objects (digital) or Network or the Internet for the main purpose of solving complex tasks that require a much higher degree of intelligence. IoT is not a distinct or single technology of its own, but rather a combination of several other technologies that work collaboratively. For this intelligence and interconnection, IoT devices are equipped with embedded sensors, actuators, processors, and transceivers or interfaces to provide the connectivity to the physical objects [1]. The implementation of the interaction and communication with the physical environment is being carried out by the IoT devices (sensors and actuators) with the collection of data to be processed intelligently in order to derive useful inferences from it. Examples of *sensors* are mobile and internet enabled phones because they have the capacity to provide inputs about their current state. An *actuator* is a device that is used to effect a change in the environment such as the temperature controller of an air conditioner [1]. Data processing and storage can be effected on the object itself or on a remote server. The output of a processed data by a device is often stored on a remote server or nearby device if it has the processing capability. Availability of limited resources is often a constraint on IoT devices as a result of limitations of size, processor and computational ability. According to Pallavi and Smruti," the main research challenge is to ensure that we get the right kind of data at the desired level of accuracy [1]. Again, in addition to the challenges of data collection, and handling, there are challenges in communication as well because communication between IoT devices is mainly wireless and they are generally installed at geographically dispersed locations" [1].

However, well-defined standards are needed for interoperability of such heterogeneous devices [1]. Standardization is impossible because of the various forms of requirements for applications and devices. Pallavi and Smruti concluded that, "the heterogeneity of devices and applications implies the creation or development of middleware platform performing the task of software interface between the *things* and *applications"* [1]. In summary, an Application Programming Interface (API) is provided through the abstraction of the hardware by the middleware for communication, data management, computation, security, and privacy [1, 3, 8].

4.2. IoT Architecture

There is no single standard agreed upon in respect of the architecture for the IoT universally but rather different researchers have proposed different architecture. However, the most basic architecture comprises of the three-layer architecture which was introduced at the early stages of research in this field [9-11].

In the three-layer architecture, the major objects are classified;

(i). The *perception layer* acts as the physical layer and responsible for sensing and information gathering about the environment [12].

(ii). The *network layer* performs the task of establishing connection with other devices or smart objects. Transmission and sensor data processing are also part of its features. Transmitting and processing sensor data are being carried by the features of this layer.

(iii). The *application layer* delivers application specific services to the user and equally defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health [12].

(iv). As per Girme, "the three-layer architecture presents the main idea of the Internet of Things, but it is not sufficient for research on IoT" [12]. The five-layer architecture additionally includes the processing and business layers alongside the perception, transport, and application. Some of the layers in the three-layer architecture performs the same role as the (the perception and application layers [12].

(v). Girme described the functions of the remaining three layers as follows (see figure 1):

a) The transport layer - the data from the sensor is being transferred from the perception layer to the processing layer through the available networks and transmission medium. i.e wireless or LAN [12, 13].

b) The processing layer - This layer carries out the analysis, storage and processing of the data emanating that from

the transport layer using available appropriate technologies; i.e. DBMS, Cloud Computing, and big data processing technology. It is often referred as the middleware layer [12]. Finally,

c) The business layer – Manages the entire IoT system and this includes, security, application, business models [12].

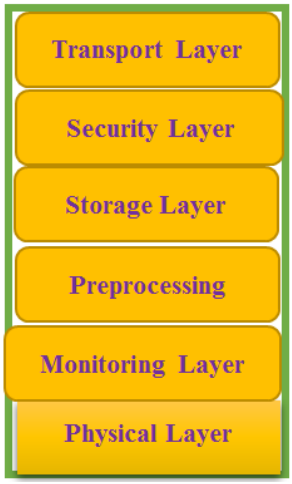

Figure 1. *FOG architecture of a smart IoT gateway. (Adapted from [1]).*

4.2.1. Examples of IoT Devices

IoT devices could be categorized into three groups:

i. consumer – smart TVs, Smart Speakers, Wearables, smart appliances, smart meters (see figure 2), [14].
ii. enterprise – examples are smart security systems, smart city technologies – traffic monitoring and weather conditions; examples are smart security systems, smart city technologies – traffic monitoring and weather conditions [14, 15].
iii. industrial – smart air-conditioning, smart hermostats, smart lighting and industrial – smart air- conditioning, smart thermostats, smart lighting [14, 15].

4.2.2. IoT Applications

IoT applications have found tremendous use in the enterprise/industry for enhancement of production, cost reduction and safety. Although domestic usage has also been on the rise as personal IoT devices and applications have flooded the market. The Smartphone revolution is a typical

Figure 2. *Smart watches and fitness trackers (Source: [16]).*

example of such devices that have successfully been introduced into the market (see Figure 3). The Smartwatches for measuring temperature, blood pressure, pulse, weather forecast equally form the growing area of IoT applications and devices that have gained considerable use by consumers. On the industrial, IoT devices have also been given serious consideration such as in the following areas:

a) Aviation/Airline – The tracking system app provision of live data during flights, customer experience through reliable and on-time flights [17].
b) Pharmaceutical – According to Anirban "Internet of things (IoT) has the power to revolutionize pharmaceutical manufacturing in processes ranging from drug discovery to remote patient access and monitoring. Several top pharma companies from around the globe are increasingly adopting IoT technologies in their manufacturing plants to achieve optimization and improve process efficiency" [18].
c) Manufacturing – IoT has helped change entire manufacturing process including how the products are designed, made and deliver, the collection of data from places that are too dangerous for human operators and also while ensuring efficiency throughout product quality [19, 20]. It has equally ensured the large production and delivery of goods in the sector with tones of goods brought to inventory on daily basis.
d) Insurance – Norman observed that the insurance industry has greatly benefitted from the disruptive IoT technology that has greatly impacted on the industry [21]. An example is the use of devices like wearables, sensors and connected vehicles that has changed the entire insurance business model with reduction in and transform the relationship with policyholders [21].

5. Features of Internet of Things

The basic features of Internet of Things are Artificial Intelligence, Connectivity, Sensors, active engagement, and usage of small devices and explained below:

Figure 3. *Internet of Things; Applications, Sensors, Storage and Human Immersion (Source: [25]).*

i. Artificial Intelligence – (AI) – IoT makes every 'thing' smart and artificial intelligence is the backbone of it. This could be viewed from the perspective of the application of a corresponding action to the result of data gathering, analysis and processing by an IoT sensor or device over the network [24, 25].
ii. Connectivity – IoT has provided new enabling technologies which is the IoT technology independent of the major network providers. In this case, provision of small scale networking at a relatively cheaper scale is guaranteed with the necessary features and characteristics. with this, IoT creates smaller networks between its system devices [25].
iii. Sensors – IoT only functions with sensors which is a key aspect of its features. Sensors act as a transformation agent for the IoT from a standard passive network of devices to an active system capable of real world integration [25].
iv. Active Engagement – Passive engagement is the standard activity of interaction with connected technology but the IoT has introduced a new phenomenon or paradigm for active content, product or service engagement [25].
v. Small Devices – The advent of IoT has resulted into the design and manufacturing of portable, smaller and cheaper devices with astonishing capabilities over time [25]. This purposely-built devices are often explored by IoT to deliver its precision, scalability, and versatility [25].

6. IoT Device Security and Management

As more Internet connected devices become widely available hackers continue to target them. The rate which the vulnerabilities are exploited has risen in the past years. Security experts have given several helpful tips to protect IoT gadgets from cybercriminals such as making sure that the default username and password is changed, update device with latest security and firmware from the manufacturer, prevent connected gadgets to access malicious websites and use encryption tool to encrypt files [22]. In the light of security, privacy and related issues associated with Networking, connectivity and the openness of the Internet, manufacturers and developers have upped the implementation of security apps and hardware to assure safety in the use of these devices. According to Nexxt, "Aside security issues, there are also other challenges that can hinder the successful deployment of an IoT system and its connected devices, such as interoperability, power/processing capabilities, scalability and availability" [22].

7. IoT and Prospects in Nigeria

As a result of the emergence of the IoT and the noticeable benefits accrued to developed nations of the world for its usage and application, there is no doubt its prospects in Nigeria as a developing nation are bright. Nigeria is confronted with several management problems in some key areas of the economy such as; agriculture, education, health, transportation, water and waste management. Despite the huge yearly budgetary allocation, the government has not been able to get corresponding results.

Nigerians, the States and Federal Government of Nigeria are not showing interest in the new technology that is taking over every aspect of life of the citizens of other developed countries the world over. The IoT is a further development of ICT and has found application in the economy, green city, smart city, sustainable developments, Insurance, body chips, transportation and traffic control, education, health, construction, manufacturing etc. According to Kachi, at the international level, IoT is a hot topic with so much potential. It is getting support from individuals and organizations but you cannot really say that in Nigeria as the subject is still considered alien. Recent media reports show that the government is willing to explore the connected world, however, it is still far from what is expected [22]. Apathy is one of the reasons Nigerians have not keyed-in into the new technology. Nigerians are not yet convinced about the new technology and its applications. Companies have also not invested seriously in IoT and the failure rate of device connectivity is still high. Security concern is also another related issue as with the advancement in the technology, hackers have also upped their attack technology. Already, the risk of performing e-transactions in Nigeria is very high and investors have been wary of losing their funds. Banks have also declared losses in Millions of naira as a result of e-transactions to fraudsters. However, the good news is that, manufacturers of these devices have gone a long way in curtailing the activities of these hackers.

8. Conclusion

There is no doubting the fact that IoT technology remains the best for Nigerian and it is high time the government and investors keyed-in into the IoT for rapid national and technological development. IoT have a very important role to play for the achievement of sustainable development goals of Nigeria. The Ecosystem, Green city, Smart City, Heating System, lightening and deployment Anti-Crime technologies. Results of study from several researchers, have established from all indications that Information and Communication Technology (ICTs) are veritable tools for sustainable development in Africa, especially when they are incorporated into Nigeria development agenda [25].

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