IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834, p- ISSN: 2278-8735.Volume 19, Issue 4, Ser. 1 (July. – August. 2024), PP 01-08
www.iosrjournals.org

Internet Of Things (Iot) Application In Nigeria: The Effect So Far And Areas Of Reconsiderations

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Abstract
The Internet of Things, or IoT, has drawn a lot of interest in recent years. IoT envisions a society in which billions of intelligent, interacting objects are able to provide both local and distant entities with a variety of services. With the help of this cutting-edge technology, users may recognize and manage services. Users can take advantage of the functional advice. The benefits and welfare that IoT brings are undeniable; This paper provides a comprehensive overview of a four-layered architecture of IoT, how IoT works and several IoT applications and points out the related key challenges. The real purpose of this paper is to assess the application of IoT in Nigeria, highlighting the effects so far especially in Energy, Water, Sanitation, Transport, Waste Management and areas of reconsiderations as compared to the developed countries.
Keywords—*Internet of Things (IoT), IoT security, IoT architecture, IoT applications, Wireless Sensor Network (WSN), Radio Frequency Identification (RFID).*

Date of Submission: 25-07-2024 Date of Acceptance: 06-08-2024

I. Introduction

The growing network of physical objects is referred to as the Internet of Things (IoT), that have IP addresses for access to the internet and the exchange of information that occurs between these items along with other Web-enabled equipment and systems [1]. The Internet of Things (IoT) is positioned to develop into a pervasive worldwide computing network that will link everything and everyone to the Internet as long as technology advances [2]. The potential to create a more personalized and fully integrated version of the current internet has been made possible by an infinite amount of creativity. We will have access to a powerful information source when every device using internet services is wired or wirelessly connected, as the number of these devices is increasing every day. While enabling communication amongst intelligent devices is a novel concept, the technologies comprising the Internet of Things are not [3]. The Internet of Things (IoT), as its name implies, is a way to combine data from various sources to any virtual platform on the Internet structure that is already in place [4].

In 1982, a customized Coke equipment that was connected to the World Wide Web and could report on its contents and whether the drinks were cold served as the inspiration for the Internet of Things (IoT) (Larnegie Mellon University). Later, in 1991, Mark Weiser introduced ubiquitous computing, which is the first contemporary understanding of IoT [5]. However, Bill Joy's 1999 internet taxonomy had some details about communication between devices [6]. Kevin Ashton used the phrase "Internet of Things" that same year to refer to a system of connected devices [7]. The primary goal of the Internet of Things (IoT) is to enable the autonomous transfer of pertinent information between discretely embedded, individually identifiable real-world devices, which are ubiquitous. Modern technologies like RFID and WSNs (Wireless Sensor Networks) [3], which interpret data sensed by devices with sensors and use it to make judgments that in turn cause automated actions enable this achievable [2].

II. IOT Architecture

The majority of issues that the workforce faces have intriguing answers thanks to the internet of things. Finding a solution is dependent on how communication devices with the best hardware and software convergence were integrated with information technology components. In the Internet of Things, the hardware and software components cooperate and act in tandem with the owner's learning outcomes-based priorities or recommendations [8]. It is helpful to think about Internet-of-Things architecture as an abstraction made up of multiple hierarchical layers. The application, middleware, network, and perception layers are the four main layers of the abstraction. Although devices inside a layer may use diverse technologies, each layer has its own unique set of technologies. A variety of services are offered by the gadgets and technologies in the Internet-of-things, each with its own specifications, limitations, and trade-offs.

Figure 1: Four-layer architecture of the IoT [9]

The IoT device layer that gives everything a tangible meaning is called the perception layer. It is composed of multiple data sensors that may detect an object's position, velocity, humidity, temperature, among other attributes. Examples of these sensors are infrared sensors, RFID tags, and other kinds of sensor networks. This layer converts pertinent information regarding items from the networked sensor devices into digital signals, which are subsequently transmitted to the network layer for further processing.

Network Layer: This level uses the digital data it receives from the Perception Level to deliver data via protocols including IPv4, IPv6, MQTT, DDS, and others to the Middleware Layer's processing systems using Bluetooth, Wi-Fi, WiMaX, and Zigbee GSM, 3G connection, etc. [10].

Middle-ware Layer: This layer is responsible for processing the data that is received from the sensor devices [3]. It guarantees easy database access by utilizing technologies like cloud storage and ubiquitous computing, enabling any relevant data to be saved there. When the information is successfully processed by some intelligent processing equipment, a fully automated action is subsequently performed in response to the processed results.

Application Layer: The processing of the data received from the sensor devices falls under the purview of this layer. Utilizing technologies such as cloud computing and ubiquitous computing, it ensures simple database access, allowing any pertinent data to be saved there. A fully automated action is then carried out in response to the information's processed results after it has been processed utilizing some sophisticated device for processing [11].

III. How Does The Internet Of Things Operate?

The Internet of Things is a massive network of interconnected gadgets. These devices send and gather vast amounts of data about the contents they store, as well as about how they work. Globally dispersed massive cloud servers collect this information. Based on the information it has received, the cloud transmits pertinent commands.

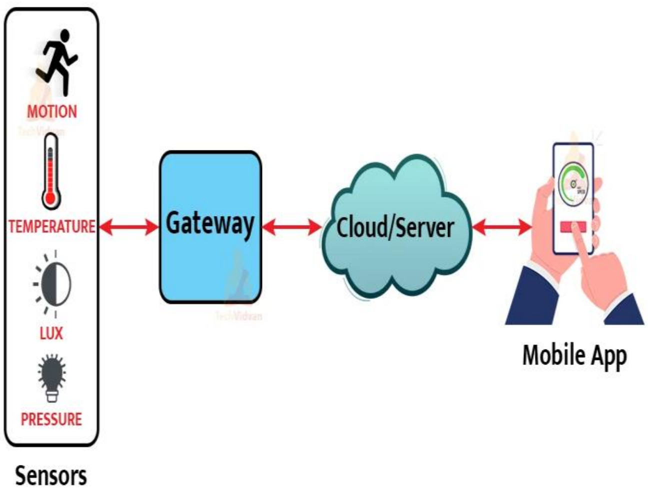

Figure 2: Working of IOT [12]

As mentioned earlier, IoT is a huge network of interconnected objects that have sensors integrated into them. These sensors are capable of detecting their surroundings. On the devices, the data is stored in some format.

These items include things like air conditioners, fire detectors, microwave ovens, cellphones, coffee makers, air conditioners, geysers, cars, and more. The inbuilt sensors in these devices constantly share data pertaining to their environment and functioning details. These devices can upload all of the data they have collected to the Internet of Things. IoT platforms include cloud servers and big database as components. The IoT platform makes advantage of the data. It processes and integrates the information. Furthermore, the platform does a thorough analysis of the data to extract relevant information. The platform then responds with instructions based on the data that has been provided. This information aggregation is shared with various devices in the end to enhance performance in the future. It's also done to improve the user experience. IoT has a very promising future. In 2020, 24 billion IoT devices were installed, by Business Insider article. ITC projects that in the upcoming years, revenue from IoT will amount to $300 billion. This creates a great deal of employment prospects in the technology sector as well as in other businesses.

IoT Applications

There are uses for the Internet of Things in practically every area of our everyday lives. Here are a few of the instances [9].

Forecasting Naturally Occurring Events: By combining sensors and allowing them to coordinate and simulate autonomously, it will be possible to anticipate the advent of landslides and other natural disasters and prepare ahead of time by taking the necessary precautions.

Applications in Industry: Applications for IoT exist in industry, such as fleet management for businesses. The Internet of Things (IoT) assists in tracking their environmental performance and processing data to identify and pick the ones that need maintenance.

Monitoring Water Scarcity: Water scarcity can be detected in different places with the help of the Internet of Things. The networks of sensors can be used to notify stream users of potentially dangerous upstream events, such as the unintended discharge of sewage into the stream, and to track long-term water interventions, like catchment area management, when they are connected to relevant modeling activities.

Design of Smart houses: By controlling energy consumption, communicating with appliances, identifying emergencies, facilitating easy-to-find items within the home, offering security, and more, the Internet of Things (IoT) can support the design of smart houses.

Uses in Medicine: The Internet of Things has the potential to save lives and enhance quality of life in the medical field. Some examples of these uses include tracking health indicators, keeping an eye on daily activities, assisting with independent living, and more. Almost every facet of our everyday lives can benefit from the Internet of Things. A few of the examples are shown below.

Applications in Industry: One use case for the Internet of Things in industry is fleet management. The Internet of Things facilitates the monitoring of environmental performance and data processing to identify and select the equipment that requires maintenance.

Applications in the Medical Field: The Internet of Things (IoT) is used in the medical field to monitor health metrics, activities, assist independent living, and medication intake, among other things, in an effort to save lives or improve quality of life.

Intelligent Transport System Architecture: The intelligent transportation system will provide efficient transportation control and management by utilizing advanced sensor, information, and network technology. Numerous intriguing features can be found in intelligent transportation, including mobile emergency command and scheduling, non-stop electronic highway toll collection, transportation law enforcement, monitoring of vehicle rules violations, anti-theft technology, lowering environmental pollution, preventing traffic jams, reporting traffic incidents, smart beaconing, and minimizing arrival delays.

Agriculture Application: A network of various sensors can gather information, process it, and notify the farmer about the areas of the field that require special care via a communication infrastructure, such as a text message sent to their mobile phone. This might incorporate intelligent seed, fertilizer, and pest control packaging that senses local conditions and indicates the appropriate course of action. Thanks to its awareness of land characteristics and climate unpredictability, intelligent farming systems will assist agronomists in developing more effective farming practices and a deeper understanding of plant growth models. This will prevent unsuitable farming conditions and hence boost agricultural yield.

Intelligent Transport System Architecture: Using cutting-edge sensor, information, and network technologies, the intelligent transportation system will offer effective transportation control and management. Numerous intriguing features can be found in intelligent transportation, including mobile emergency command and scheduling, non-stop electronic highway toll collection, transportation law enforcement, monitoring of vehicle rules violations, anti-theft technology, lowering environmental pollution, preventing traffic jams, reporting traffic incidents, smart beaconing, and minimizing arrival delays.

Smart City Design: The Internet of Things (IoT) can assist with aspects of smart city design such as air quality monitoring, emergency route identification, effective city lighting, garden irrigation, and more.

Smart Metering and Monitoring: Accurate automated meter reading and client invoice issuing are made possible by the Internet of Things (IoT) design. Such a system for gas, water, and environmental metering and monitoring, as well as remote monitoring and maintenance of wind turbines, can be designed using the Internet of Things.

Smart Security: Applications of IoT technology include space surveillance, asset and person tracking, infrastructure and equipment maintenance, alarm systems, and more in the security and surveillance domain.

IV. Effects Of IOTS In Nigeria

Energy

Nigeria's energy industry has a high need for IoT solutions, which has been fuelled by recent government initiatives. The Nigerian government made known plans in 2020 to implement service-based tariffs in an effort to address the core issue facing the country's energy sector: low prices that fail to cover expenses result in underinvestment and subpar performance. However, political opposition to higher tariffs stems from this subpar service. By tying the price, a customer pays to the level of service they receive, the new tariffs seek to end this cycle**.**

In order to successfully implement service-based tariffs, Nigeria must install smart meters, which can assess service quality by giving real-time information on residential energy consumption. The metering gap is estimated to be greater than 10 million, according to the Nigeria Electricity Regulatory Commission (NERC). As a result, the NMMP was created, which offers government-backed loans to regional energy distribution firms so they can buy meters from regional producers like MOJEC International.

Device(s) and Used case	Description	Benefits
Meters: Smart metering	• Real-time, accurate recording and automatic transmission of energy usage data	• Enables utilities to implement time-based tariffs to manage demand; • Facilitates alternative energy planning and modeling; • Removes the need for staff to visit customers' homes or rely on them to report by themselves the meter reading; • Allows for savings in costs, theft of electricity monitoring, etc.
Sensors (e.g. current, voltage): Smart grid	• provides measurements of voltage sags, swells, interrupt information, and more parameters while tracking the distribution network in real time.	• Lowers the likelihood of penalties from service level agreement (SLA) breaches; • Facilitates faster problem detection and resolution, enhancing customer experience; and • Allows energy businesses to reallocate resources when grid demand increases.
Meters, sensors (e.g. current, voltage): Microgrids	• integrated sensors to track output and distribution on solar photovoltaic (PV) systems, such as large-scale solar farms or microgrids managed by smallholders	• Prevents emissions from fossil fuels, primarily coal. • Uses stored energy to optimize power use at residential and commercial buildings (instead of depending on the grid)
Meters, sensors (e.g. temperature), GPS: PAYG cooking and SHS	• Linked LPG cylinders and electromagnetic induction stoves are examples of IoT-enabled products. • Solutions gather usage information and communicate it to users (e.g., reminders to make payments, charge batteries).	• Why Provide impoverished customers with more affordable services since they can make little payments. • Permits unbanked consumers to score credit • More efficient ways for service providers to collect money

Water

In 2018, Nigeria's president declared a state of emergency in the water sector due to the lack of access to clean drinking water for 60 million people, or thirty percent of the nation's population. Expanding the water supply is hampered by small distribution networks, insufficient power from the national grid, and frequent pipe breaches. It is estimated that Lagos alone will need to invest an additional N300 billion (~$680 million) year in order to achieve universal access to clean water [13]. To narrow this disparity, donor support will be essential. The World Bank, USAID, and WaterAid have all committed to further supporting Nigeria's water industry as of 2021. This could open up the possibility of investigating how IoT solutions could enhance the availability of water, an area that has gotten relatively little funding up to this point. Using IoT technology to remotely monitor vital infrastructure is one example [14].

Device(s) and Used case	Description	Benefits
Meters: Smart metering	• Real-time, accurate recording and automatic transmission of water usage data	• Easier to find and patch leaks, allowing utilities to save their NRW expenses; • Better reading accuracy and lower personnel costs

		• Offer additional services (such as a PAYG option for clients with lesser incomes). • Offers insight into Ph levels and water contamination
Meters, connected water purifiers, pH sensors: Water ATMs	• Water is automatically dispensed by ATMs when customers make a payment. • IoT connectivity allows for real-time monitoring of ATMs.	• Makes the amount of water distributed and the number of consumers visible. • Evaluates water quality and leaking • In order to purify water, some methods mix water ATMs with a water treatment solution.
Connected water purifiers, pH sensors, oxidation reduction potential (ORP) sensors: Water treatment	• Monitors filter consumption to make sure filters are changed when needed to prevent impurities from getting into the system. • Calculates the downstream water's chemical characteristics.	• Prevents noncompliance by limiting water alkalinity to acceptable levels and averting possible health hazards. • Minimizes maintenance and downtime for the system
Water flow meter, sensors (pressure, temperature): Supply network monitoring	• Keeps an eye on pipe pressure and flow to identify leaks and anticipate bursts. • Monitors the safety valve's output temperature, which drops sharply prior to a leak.	• Makes early fault detection possible to prevent unplanned maintenance and shutdowns. • Increases the water pipe network's uptime

Sanitation

A nationwide initiative known as Clean Nigeria: Use the Toilet was started in response to the proclamation of a state of emergency with the goal of ending open defecation in Nigeria by 2025 (WHO, UNICEF, 2019). In light of this, there is a need for greater private sector involvement in the sanitation industry, which presents an opportunity for regional entrepreneurs to employ IoT and other digital technologies to address the issue. Nonetheless, our research revealed no evidence of IoT being used to support the sanitation sector's service delivery, and there is still a dearth of knowledge regarding how to integrate the private sector. In 2021, the Toilet Board Coalition published a paper detailing Nigeria's potential to use smart technologies in the sanitation industry [15].

Device(s) and Used case	Description	Benefits
Sewer level monitoring sensor, acoustic sensor, camera: Wastewater monitoring	• Installing sensors in sewer and canal lines to track sewage flow, breaks, and leaks	• Advances knowledge of pathogen abundances in rivers Enhances comprehension of the potential of sewage for upcycling
Ambient monitoring sensor, motion sensors: Smart toilets	• Offers information about the cleanliness and use of public restrooms.	• Reduces maintenance requirements by automating the toilet cleaning
Fill level sensor, vehicle tracker: Pit fill level monitoring	• Monitoring levels of water and overflows using IoT devices and sending alarms as necessary • It can be coupled with service vehicle real-time tracking.	• Ensures faecal sludge disposal is safer and more effective for a healthier and cleaner city.

Transport

The majority of Nigerian mobile providers' IoT initiatives have been directed toward connection. Nonetheless, there are certain outliers. For instance, MTN offers a range of fleet management services to the transportation sector, i comprising driver management, vehicle monitoring, and asset tracking. Since these IoT use cases are among the most well-established in Nigeria, many other companies, such as publicly traded LoRaWAN providers like Nova Track Limited and regional IoT start-ups like Gricd, are expressing interest in them.

Device(s) and Used case	Description	Benefits
Vehicle tracker, CCTV cameras: Smart public transport	• Transport operators and commuters can check the whereabouts of public transportation vehicles thanks to real-time tracking. • Additional information about vehicle operation can be provided to transport operators.	• The public transportation system is more dependable and predictable for passengers. • Improves the standard of long-term urban planning and public transportation • Vehicle and rider safety can be enhanced by onboard cameras.
Charging point sensors, EV sensors:	• EVs with sensors to track fuel usage and routing	• CO_2 reductions by using EVs' integrated sensors and switching from fossil fuels to electricity

EVs	• Location beacons for passing EVs are provided by EV charging point sensors.	• Charging point sensors prevent unnecessary emissions from coming from looking for a charging station.
Trackers and sensors (e.g. temperature, humidity, moisture): Asset tracking	• To track transit, IoT sensors can be fastened to pallets, shipping containers, trailers, and even individual products.	• Lowers the number of misplaced things • Assists businesses in making sure their goods are carried in an appropriate manner
Light detection and ranging (LiDAR) sensors, GPS/ GNSS, gyroscopes, accelerometers: Drones for deliveries	• Goods (like medical supplies) can be transported from one place to another using drones.	It Offers a delivery service that is more efficient and environmentally friendly (under some circumstances) than using traditional methods.

Waste Management

In Nigeria, the majority of waste management is done informally and is typified by disaggregated rubbish pickers, overflowing landfills, and dump sites. Lagos is a prime example of this, producing over 13,000 metric tons of rubbish each day, of which only 40% is collected by municipal authorities [16]. To assist address the issue, creative private sector solutions are thus required. Up until now, IoT has had a very little impact on Nigeria's waste management industry.

Device(s) and Used case	Description	Benefits
Trackers (container, vehicle, workforce), fill level sensor, temperature sensor: Smart bins	• Makes it possible to remotely monitor garbage containers' locations and fill levels. • Frequently paired with service vehicle real-time tracking	• An alert is set to plan a pickup for a waste container that is almost full, even in advance of the prearranged time. • Predicting future demands is made easier by knowing the location of emptying patterns.
Scales, sensors (e.g. ultrasonic, colour), servomotor: Smart recycling	• Recycling garbage can be weighed with IoT devices. • Waste segregation can be automated using more advanced equipment.	• Boosts rates of recycling • Minimizes the proliferation of microbes and the open decomposition of organic waste.

Challenges of IoT

Due to several obstacles, creating a successful Internet of Things application is still a difficult effort. These difficulties include those related to mobility, interoperability, scalability, management, availability, and security and privacy. We provide a brief description of each of these challenges below.

Mobility: IoT devices need to be mobile enough to roam about freely and modify their IP addresses and networks to fit their environment. As a result, the routing protocol, such as RPL, has to rebuild the DODAG each time a node joins or departs the network, adding a large overhead. Mobility may also result in a change in service providers, which might introduce additional complexity due to gateway changes and service interruptions.

Reliability: The system must to function flawlessly and fulfil all of its requirements accurately. In situations where emergency answers are necessary, it is a very important requirement. In Internet of Things applications, the system needs to be extremely dependable and quick in gathering information, sharing it, and making decisions. In the end, making the wrong choice can have fatal results.

Another issue with IoT applications is scalability, as billions or even millions of devices may be connected to the same network. Controlling their dispersion is a difficult undertaking. Furthermore, IoT applications need to be built to support extensible services and operations in order to be able to withstand new devices and services continuously joining the network.

Management: One of the biggest challenges in the Internet of Things is managing all these devices and monitoring their performance, configurations, and failures. It is the responsibility of providers to oversee and take responsibility for the Fault, Configuration, Accounting, Performance, and Security (FCAPS) of their networked equipment.

Availability: Service members can access software and hardware versions of the Internet of Things at any time and from any location. Software availability denotes the ability of the service to be accessed by anyone who is granted permission to do so. Hardware availability indicates how accessible and interoperable the current devices are with IoT protocols and capabilities. Furthermore, these protocols need to be small enough to fit into IoT-constrained devices.

Interoperability: Heterogeneous devices and protocols must be able to cooperate with one another in order to be considered interoperable. The fact that IoT systems employ so many different platforms makes this difficultApplication developers and device manufacturers should oversee interoperability in order to deliver services regardless of the hardware specification or platform that the client employs.

Challenge Description: Cooperation in the IoT, several protocols and architectures are vying for market dominance and standardization, just like with any other emerging technology. While some of these protocols and architectures are open-source, others are built using proprietary components. This issue is being lessened by recent IoT standards, yet different protocols and implementations for IoT networks are frequently accessible. the widely used architectures and protocols, particularly the open, standards-based versions.

V. Areas Of Reconsiderations As Compared To The Developed Countries

There are certain difficulties in implementing IoT, but its advantages and wellbeing are indisputable. As the globe becomes more digitally oriented, developing nations such as Nigeria acquire technology rather than creating it themselves. They become reliant on digital world designers as a result of this method. Nigeria must therefore be suited for the adoption of new technologies.

Each country has its own IoT implementation pace and strategy. Gaining flexibility to boost productivity is a top priority for nations with wide product offerings. On the other side, the nation should embrace a quality-focused strategy to reduce the number of subpar goods. IoT is necessary for this method's data mining-based system optimization. In contrast, because of their large labour force, wealthy nations like Nigeria are concentrating on raising the rate of automation.

Nigeria should re-evaluate a few structural obstacles that stand in the way of the complete adoption of IoT.

1. **Limited Skill in the Workforce**: This is one of the issues impeding the uptake of new technologies. Additionally, labour force quality varies among industries. Another disadvantage is the low representation of value-added products, given the growing demand for these items throughout the world.
2. **Lack of standardization**: IoT practitioners face a dearth of standards. As standards change daily, technological adoption becomes more challenging.
3. **Lack of Mobility:** Another issue with IoT activities is this one. Mobile users can access the numerous services provided by this cutting-edge technology.
4. **Infrastructure:** For developing nations like Nigeria, this is a major concern. IoT applications must have a more advanced infrastructure. Consequently, devices that are networked can function quickly and effectively**.**
5. **Bad Internet Connectivity:** The nation has difficulties as a result of poor internet connectivity. IoT requires the internet, hence a nationwide internet network is required[17][18].

Solutions

Interoperable Standards/Infrastructure: is a problem that can be resolved with greater standardization efforts. Nigeria should participate in the cooperative effort being conducted at the ITU-T Study Group 20 level to standardize IoT and create smart cities and communities. Additionally, as IoT is expanded across sectors, cross-sector collaboration would greatly improve the situation by exchanging ideas and addressing regulatory and standardization difficulties.

Security and Safety: This is another issue that has to be resolved. IoT developers need to create a strong, highly secure system that can withstand hacking, including Zero Day Attacks and other black hat hacking techniques like Distributed Denial of Service (DDOS), which can render online services unavailable by flooding a targeted system's bandwidth or resources with multiple systems using compromised systems, such as botnets. This could be used by terrorist strikes that capitalize on Internet of Things vulnerabilities.

VI. Recommendation

Other elements that are not mentioned in this paper would undoubtedly have an impact on Nigeria's IoT deployment. To learn more about these instances, more investigation is necessary. The successful implementation of IoT and Smart Cities in Nigeria is contingent upon the existence of government policies that provide an excellent foundation. Not much can be accomplished in the absence of government will.

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