FINAL REPORT

Study on Next Generation Networks and Internet of Things (IoT)

December, 2020

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EXECUTIVE SUMMARY

The Internet of Things (IoT) has started to significantly affect many aspects of the economy and is considered to possess the potential to unleash immense economic growth if properly harnessed.

As the IoT growth shifts from the historically strong digital economies in the global North to the emerging markets in the global South particularly Nigeria, new Industry leaders will emerge bringing innovation and technology with them. This new generation of tech entrepreneurs has the opportunity to use technology to solve local problems, reach global markets and drive innovation. As more people benefit from coming online, the opportunities and revenue streams will expand. These new generation entrepreneurs will play a crucial role in mapping the direction of travel of Nigeria's digital economy.

While the IoT may rely to a large extent upon the existing hardware infrastructure, new software must be written to support the interoperability between numerous heterogeneous devices and searching the data generated by them. Nigerian techies have a chance to muscle in to this space and create value. Start-ups will be able to scale more quickly, accelerating past the traditional paths of company growth.

Increased IoT penetration will reshape the economy in ways stakeholders, particularly regulators and policymakers may be ill-equipped to keep pace with. Its impact will be pervasive in almost all sectors of the economy especially communication, education, health, agriculture, housing, transportation, Government and society at large.

The proliferation of IoT poses challenges for Industry, policymakers, regulators and consumers alike. The challenges are significant both in complexity and scale. Prominent among them are issues around provisioning of the necessary infrastructure, spectrum licensing, ethics, digital skills, privacy and security. How the Government responds to these challenges will impact not only the economy but also the wider propagation of the Internet of Things.

The research design chosen for this study was an in-depth, hybrid quantitative-qualitative method to fully understand the broad trends and underlying nuances of consumers' access to, use of and experiences with the IoT. From the transformations of the Internet economy to the effects of regulations and policies, several unique trends and concerns that may impact the future of IoT in Nigeria are identified. The research produced results as follows:

(i) Identifiable pathways to create an enabling environment to stimulate production of IoT devices in Nigeria that are of international standards and can compete globally;

(ii) Pragmatic approach towards the setting up of technology incubation centres and assisting technology start-ups to scale across Nigeria; and

(iii) Policy guidelines that will ensure security and privacy of IoT services in Nigeria.


Internet of Things (IoT)
Internet of Things
Everything will be connected.

CHAPTER ONE

Project Background

1.1 Introduction

The Internet of Things (IoT) envisions scenarios where objects, animals or people are provided with the ability to transfer data over networks through the use of standard communication protocols. More generally, the IoT holds the promise of creating a global network supporting ubiquitous computing and context awareness among devices; allowing dissimilar everyday objects to understand their environment, interact with it and make decisions.[1] The Internet of Things consists of two foundational aspects - the Internet itself and the 'things' that leverage networking, sensing and actuation capabilities to sense the physical world and act on it.

The IoT is proliferating rapidly as both stand-alone devices and embedded sensors in all types of electronic devices, from household appliances to industrial equipment. IoT has grown to encompass wide-ranging uses from physical fitness to industrial scale mechanisms for manufacturing. It comprises technology for smart homes and smart buildings; smart communities and smart cities; automation of industrial production systems; and, Government tracking of growth and management of security, defence and border control systems.

Due to high utility, low cost and ease of deployment, IoT is extending the reach of the Internet to inexpensive, miniature, pervasive computing and control devices. The possibility of such a framework that would allow direct machine-to-machine, machine-to-things, things-to-people and people-to-machine communications on internal networks or over the Internet has led hardware and software developers to contemplate bringing more things online and allowing them to participate in the web as a vast network of autonomous, self-organizing objects. Such things may also be deployed in stand-alone IP

[1] "Towards a Definition of the Internet of Things (IoT)," Roberto Minerva, Abyi Biru, Domenico Rotondi; IEEE Internet Initiative, iot.ieee.org; May 27, 2015.

networks not connected to the Internet and are unambiguously identified using the existing unique identification standards, such as the many Universal Resource Identifier (URI) schemes. With their sensor and activation capabilities, the things establish relationships between the digital and physical worlds that did not previously exist.

IoT heralds a tech ecosystem that is far grander in scale and opportunity than previously imagined. There are estimates that IoT has the potential to generate over $19 trillion of value over the coming years.[2] The staggering potential size-of-the-prize has certainly caught the attention of the world's business community. In a survey, 96% of senior business leaders around the globe said their companies would be using the IoT in some way within the next 3 years, while 68% said their companies are already investing budgets in the IoT.[3]

However, the impact of IoT raises significant concerns that could stand in the way of realizing its potential benefits. These concerns include:

(i) Security of internet connected devices
(ii) Technical challenges for standards
(iii) Policy and development challenges

This Report presents identifiable pathways to equip the IoT consumers, Government and Industry with suggestions and recommendations to address these concerns and unlock the opportunities and advantages inherent in the IoT.

[2] Didier Bonnet, Jerome Buvat, Subrahmanyam KVJ; Monetizing the Internet of Things: *Extracting Value from the Connectivity*
[3] PSFK (2014), report: "A Brief History Of The Internet Of Things", http://www.psfk.com/2014/03/internet-of-things-infographic.html

1.2 Research Focus

In line with the Terms of Reference (ToR), the study's central focus is on seeking ways to stimulate the development, deployment and use of IoT services in Nigeria.

1.3 Objectives

The main objective of the study is to provide Nigerian Communications Commission (NCC) with a comprehensive report on ways to accommodate and accelerate the development of IoT in Nigeria.

The study seeks to provide answers to the following overarching questions:

- What are the effective ways to encourage the use of IoT at all levels especially Government agencies, corporate bodies and individuals taking into cognizance existing resources such as frequency and infrastructure availability to increase broadband penetration levels in the country?
- What cost-efficient frameworks and models can be deployed for the setting up of technology incubation centres in Nigeria which will ultimately help promote the development of IoT and drive its development and deployment?
- What are the new revenue streams that can be used to stimulate the growth of Nigeria's tech ecosystem?
- What policy guidelines can be suggested to improve security and assuage privacy concerns in using IoT?
- Are there regulatory incentives for deployment of IoT by corporate bodies such as utility companies, logistics amongst others? What regulatory incentives can be introduced for IoT friendly service providers?
- How can IoT improve the economic status of Nigeria?
- What are the current and future uses of IoT across the globe?

- Are there recommendations on suggested amendments to existing licences and/or regulations of the Commission to support the growth and implementation of IoT?
- What are the ethical issues regarding IoT?
- What infrastructure needs and gaps exist slowing down the implementation of IoT?
- What are Nigeria customer needs and expectations from IoT?
- What and where are the competitive market forces requiring IoT?
- Is there a need and market for IoT in Nigeria?
- What are the best models, products and segments of IoT that will likely thrive in Nigeria?

1.4 Scope

The Study covers the entire thirty-six (36) States of the Federation and the Federal Capital Territory (FCT) and is conducted through the lens of the following four headings:

- **IoT Devices**

The study suggests ways to create an enabling environment that will stimulate production of IoT devices that are of international standards and can compete globally. This is to push for local content in the telecommunications Industry.

- **Improving Nigeria's Tech Ecosystem**

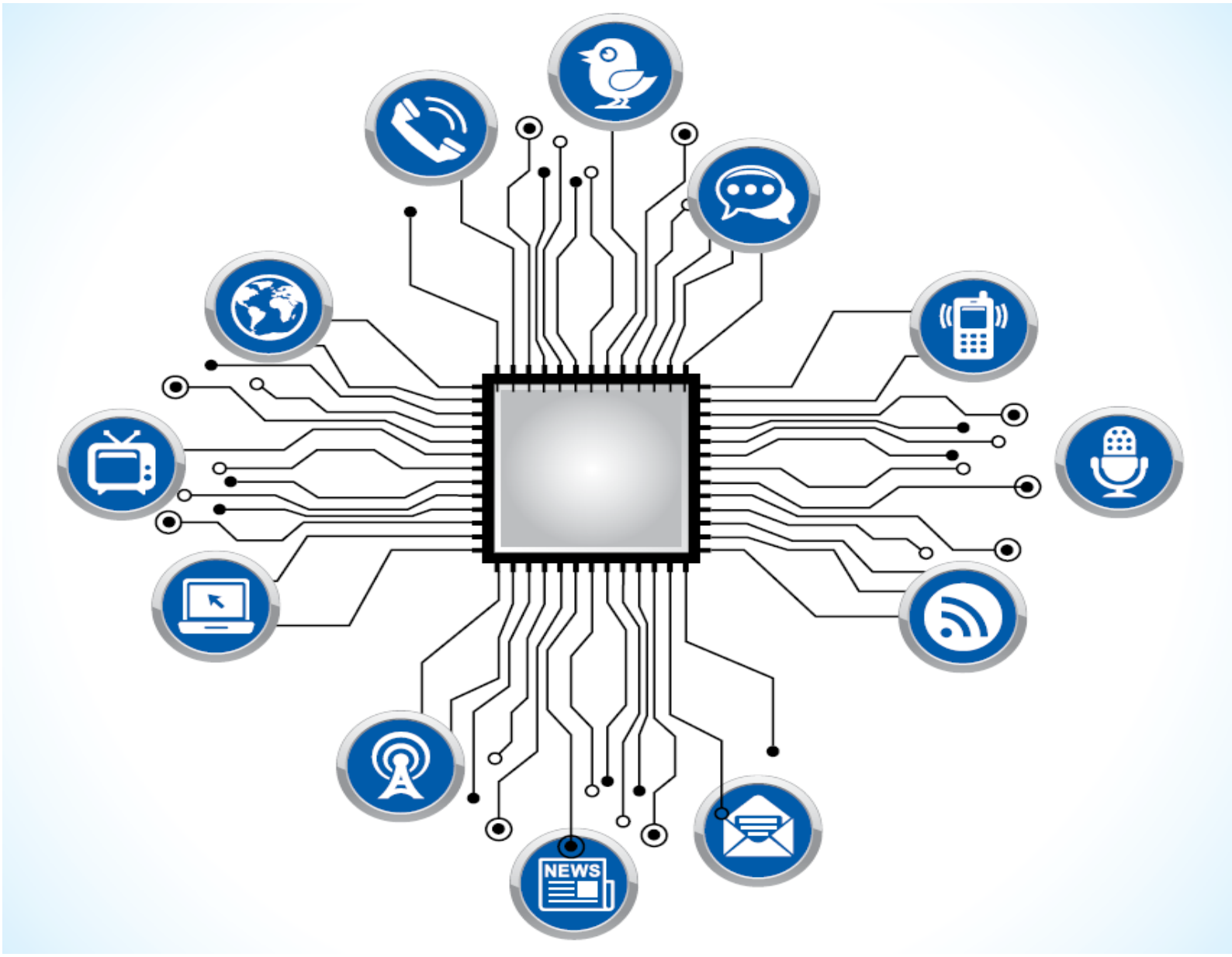
The study comes up with pragmatic approach towards the setting up of technology incubation centres and assisting technology start-ups to scale across Nigeria.

- **Security and Privacy of IoT Devices**

The study suggests policy guidelines that will ensure security and privacy of IoT services in Nigeria. IoT devices, applications and services generate a vast amount of data about their users. This is potentially dangerous if not properly guarded.

- **Financing Tech Start-ups**

One major problem hindering technological advancement in Nigeria has been lack of finance. Banks are reluctant to buy into ideas of bright Nigerian innovators. Similarly, Nigeria Government revenues are insufficient to fund a dynamic and proactive tech ecosystem. The study identifies new revenue streams which can be used to finance tech start-ups profitably.



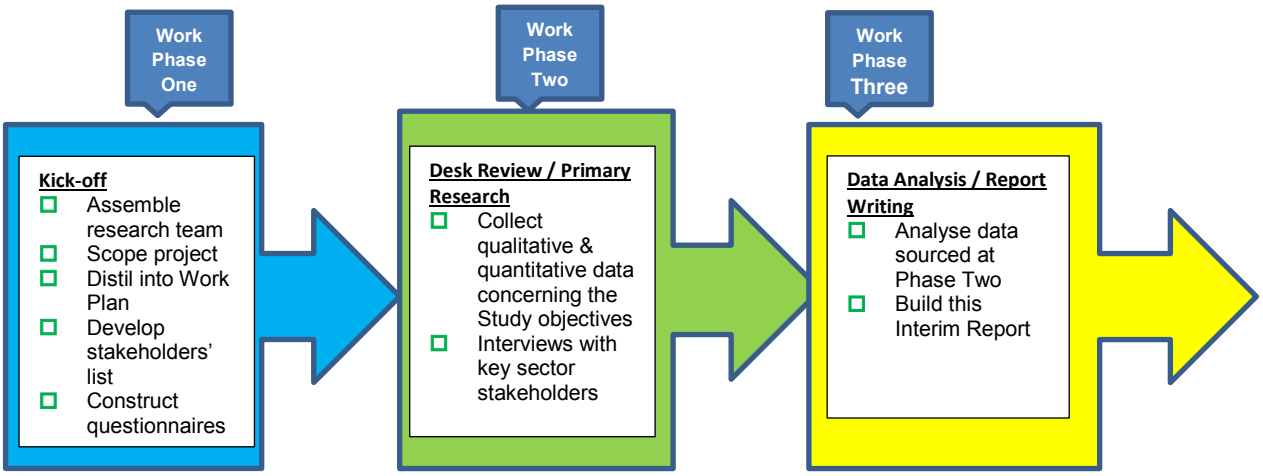
CHAPTER TWO

Methodology

2.1 Research Methodology and Work Plan

The study was conducted in three parts. Part 1 involved the inception phase; Part 2 entailed the field work, data analysis and reports; and, Part 3 dealt with study conclusion, Final Report and presentation to client and Industry stakeholders.

Part 2 of the study had three phases. Phase 1 was concerned with assembling the research team and scoping the phase-level works, rendering the scope into a Work Plan, developing a comprehensive stakeholders' list and constructing the survey questionnaires.



Phase 2 was given over to desk review and primary data collection involving the team collecting qualitative and quantitative data and carrying out interviews with respondents.

Phase 3 commenced with the analysis of the data sourced in Phases 1 and 2 and the construction of the Executive summary and the Final Report.

The work activities in Phases 1, 2 and 3 of Part 2 expanded on the milestones achieved in Part 1 that comprised the inception phase of the study.

Activities undertaken during the inception phase included:

- Analysis of the ToR, firstly among the technical team and secondly, within the enlarged Project Delivery Team (PDT) with elaborate team discussions across the internal responsibility matrix;
- Preparation of draft questionnaires and interview checklists and their discussion with carefully selected relevant stakeholders;
- Contacts with key sector stakeholders across the 36 States of the country and the FCT for the purpose of scheduling visitations and dates for focus group meetings;
- Identification and detailed description of the tasks to be performed which were distilled into the Work Plan;
- Kick-off meeting with the Research & Development Department (R&D); and
- Submission of Inception Report and subsequently, the Interim Report.

2.2 Data Collection Instruments

The research team gathered data through the following methods:

- Desk Review
- Field Survey / Questionnaires[4]
- Round Table Consultations
- Interviews

[4] See Appendix Four: Field Survey Questionnaire for Individuals

- **Desk Review**

  The team focused particularly on materials from the World Wide Web, NCC Policy documents, legacy research papers, IoT and related technology journals, publications and newsletters from institutions active in the IoT sector, international white papers and Government position papers on IoT.

  The main purpose of the desk review was to situate IoT in the context of the study's ToR vis-à-vis trends, use cases, uncertainties, hindrances and the way forward. The desk review yielded comprehensive and useful information around the nature of IoT and the impact of existing policies, legal framework, hardware and software on its propagation in Nigeria.

- **Field Survey**

  Opinions were canvassed from technology consumers, policymakers, and the Industry[5] across the thirty-six (36) States of Nigeria and the FCT using both physical questionnaires and online channels. The online survey was designed based on key trends identified in the desk review. It measured respondents' perception of the trends and their impact on the evolution of IoT in Nigeria.

- **Round Table Consultations**

  There were good responses from stakeholders through frank and robust responses to the questionnaires. The project team had consultations with several Government agencies and the Industry.

- **Interviews**

  The interviews complement the physical and online surveys. The interviews provided the opportunity to ground-truth the findings from the desk review and solicit inputs on the overarching questions and issues of the study.

[5] See Appendix Five: Field Survey Questionnaire for Industry and Policymakers

2.3 Sampling Size and Sampling Techniques

A total number of 3665 respondents participated in the survey from across the thirty-six 36 States and the FCT. The survey sample was slightly skewed toward a younger segment of the population between the ages of 13 – 35 years of age as they constitute around 55% of the population of Nigeria[6].

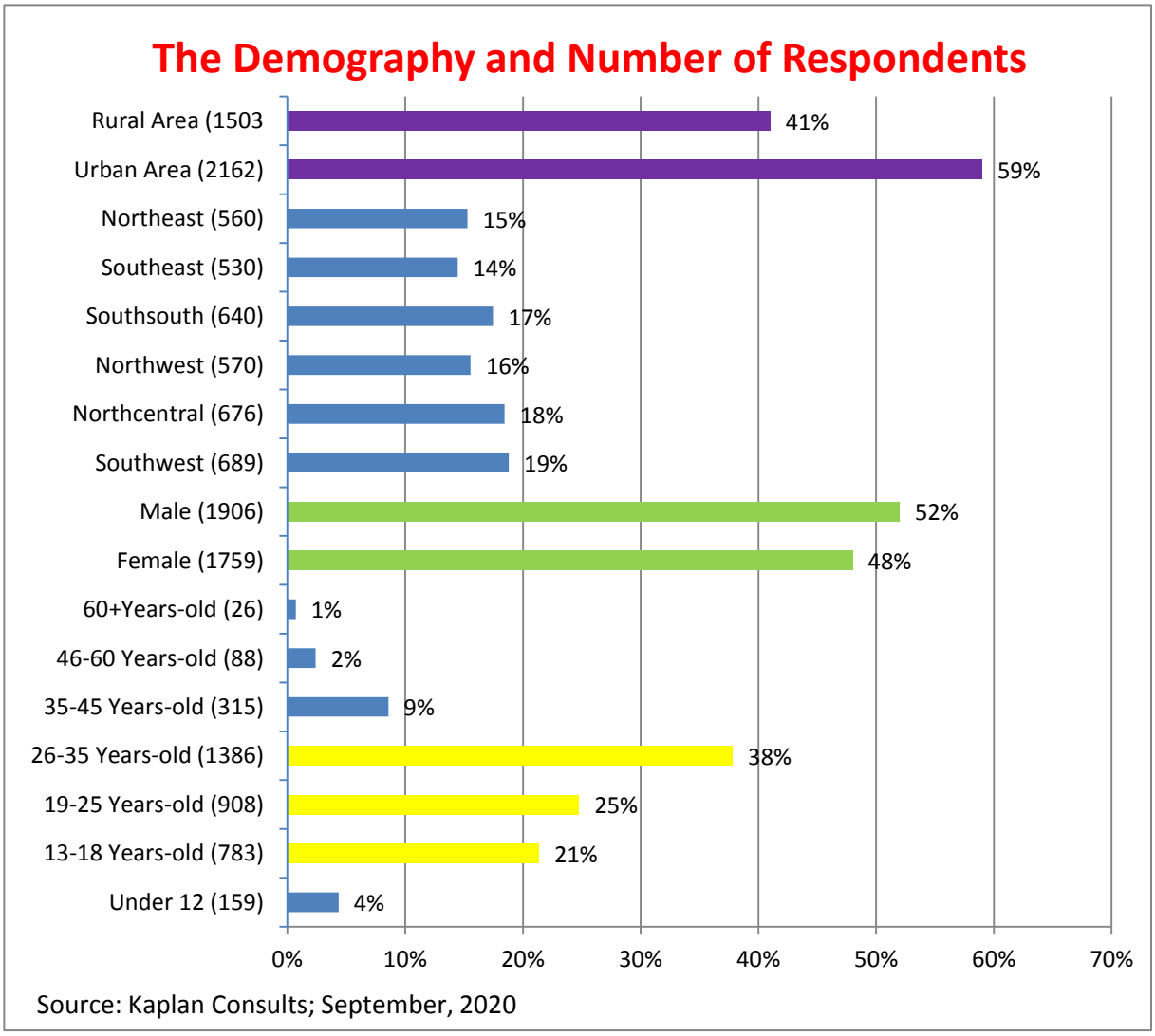


Table 1: The Demography and Number of Survey Respondents

[6] 2016 Nigeria Census

The survey was stratified along the six subsisting geo-political zones with proportional representation between the urban and the rural area clusters. The urban and rural areas returned 41% and 59% participation respectively.

The Southwest has the largest number of participants with 689 respondents or 19% of the total. Northcentral came in with 676 respondents at 18%, Southsouth 17% with 640 respondents, while the Southeast brought up the rear at 530 respondents or 14% of the survey total.

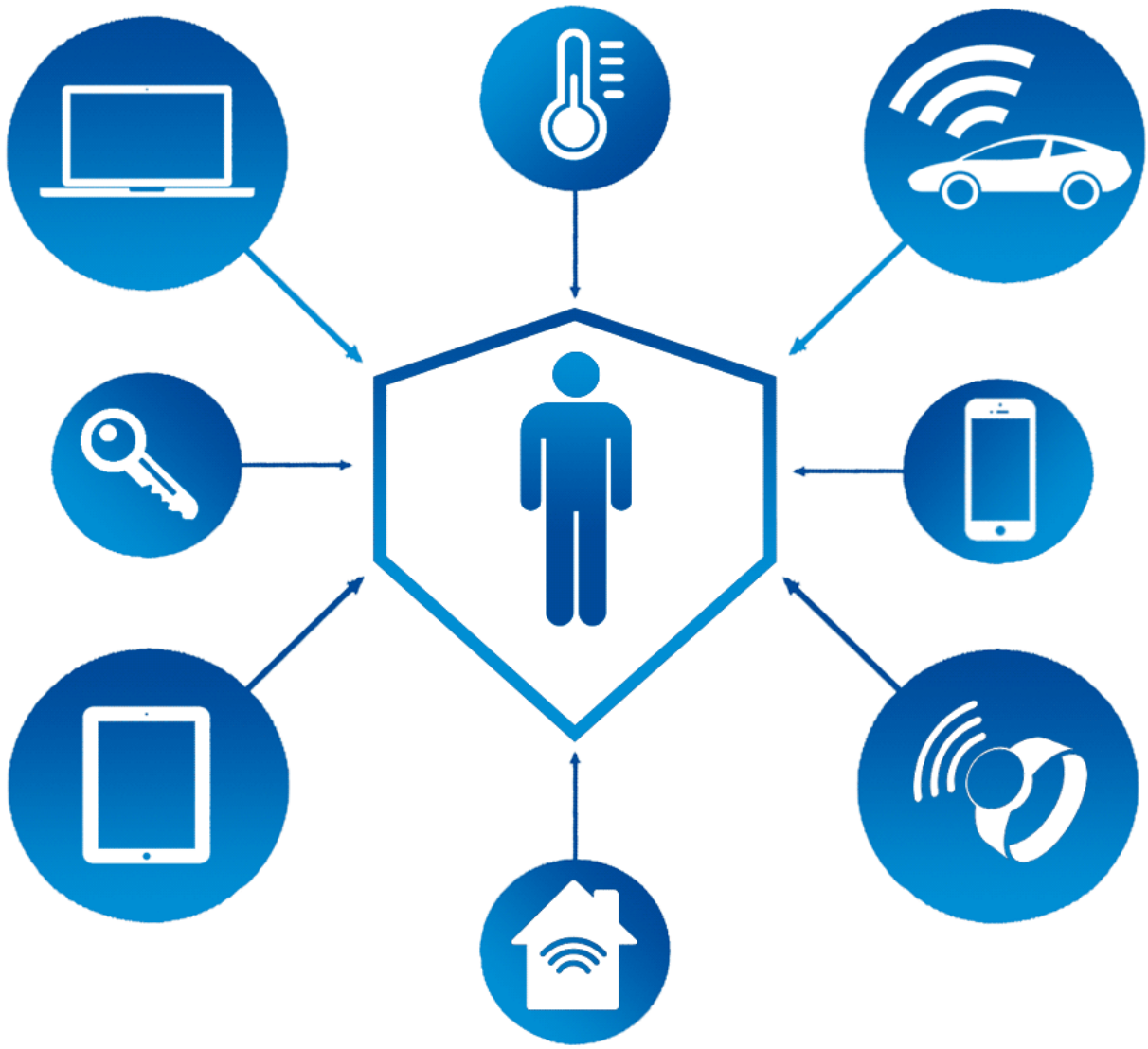
Fifty two percent (1906) of the survey participants were males and 48% (1759) females.

2.4 Survey Limitations

The Covid19 pandemic struck at a most inopportune phase of the survey when the study resource persons were already mobilising to the field. Activities stalled as directives were awaited from the Federal Government leaving the team unable to adhere to the timescales outlined in the contract's ToR.

Although fettered by Covid-19 restrictions, the team strove for equal sampling representation between urban and rural areas by ensuring that all thirty-six (36) States of the Federation and the FCT were surveyed in stratified and clustered sample sizes.

Fortuitously, the Federal Government and State authorities eventually relaxed most of the movement restrictions which then allowed the remobilisation of survey operatives to the field.



CHAPTER THREE

Results and Findings

3.1 The Results and Key Findings

- **IoT Devices**

Most devices currently shoring up the Internet such as servers, desktops, laptops, and tablets were originally designed to be part of the Internet and have integrated processing, storage and network capabilities. What the IoT represents is a revolution of the use of these existing technologies in terms of the number and kinds of devices as well as the interconnection of networks of these devices across the Internet.

The Internet of Things is anchored on the notion that everything can be equipped with tracking, sensing, processing and networking capabilities that will enable it to understand its environment, make data-driven decisions and perform tasks.

In 2016, the global digital economy was worth some $11.5 trillion, equivalent to 15.5% of the world's overall GDP. It is expected to reach 25% in less than a decade, quickly outpacing the growth of the overall economy.[7] However, Nigeria is currently capturing only a fraction of this growth and needs to strategically invest in the foundational elements of the digital economy to keep pace.

Nigeria is one of the emerging markets with appreciable potential to be a big player in the huge and pervasive IoT devices market. To underscore the size of the IoT devices market, Cisco, in a widely publicised white paper, predicted that over 50 billion 'things' will be connected to the Internet by 2020, rising to double that number before the end of the decade.[8]

[7] Digital Spillover, Measuring the true impact of the digital economy, Huawei and Oxford Economics 2016
[8] https://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf.

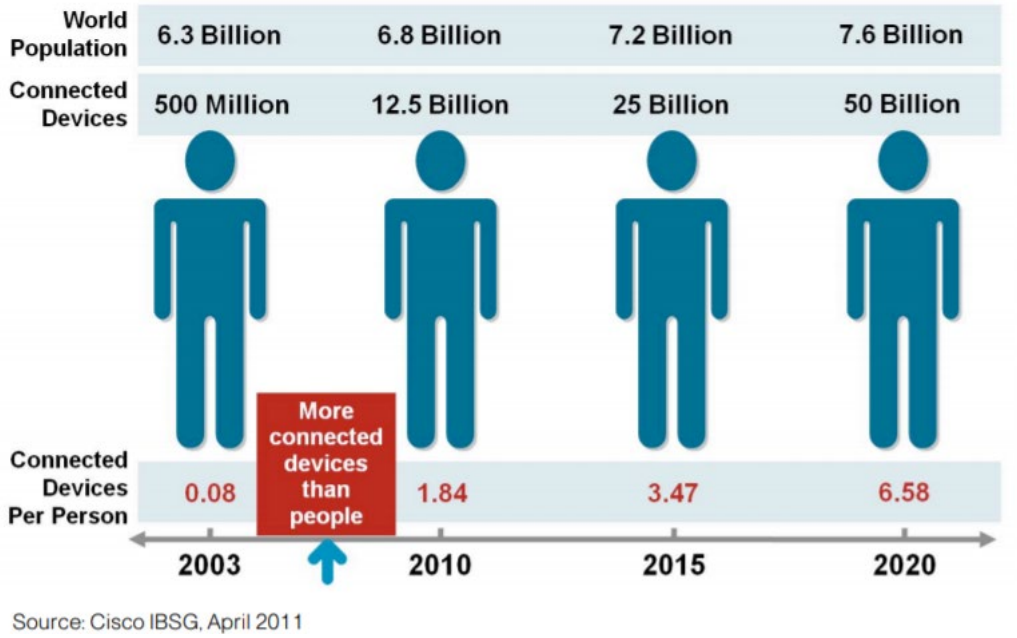


Figure 1: World Population vs. Connected Devices

The prediction purports that in the fullness of time 99% of everything produced will be connected to the Internet; these connected things may range in scale from smartphones to smart cities, smart vehicles, smart grids, smart agriculture, and so on.

The IoT opportunities abound in both domestic and industrial spheres of the economy. There are, for instance, thousands of homes and offices in Nigeria with neither fire nor intrusion detector systems. In the same vein, many industrial outfits do not have systems in place to monitor and measure air quality in and around their facilities. Many of them do not have smoke detection systems in place to give early warning of smoke or fire.[9]

The impact on the employment landscape, especially in the number of technologists that would be required were there to be a regulatory requirement making such environmental monitoring measures mandatory can only be imagined.

[9] Statistical Analysis of Fire Outbreaks in Homes and Public Buildings in Nigeria: A Case Study of Lagos State

The core concepts underpinning the IoT are not new. The idea of direct machine-to-machine communication is basic to the Internet in which desktops, servers and routers communicate with each other. The RFID and sensor networks have been in use for years to track products through the supply chain or in industrial and manufacturing settings[10].

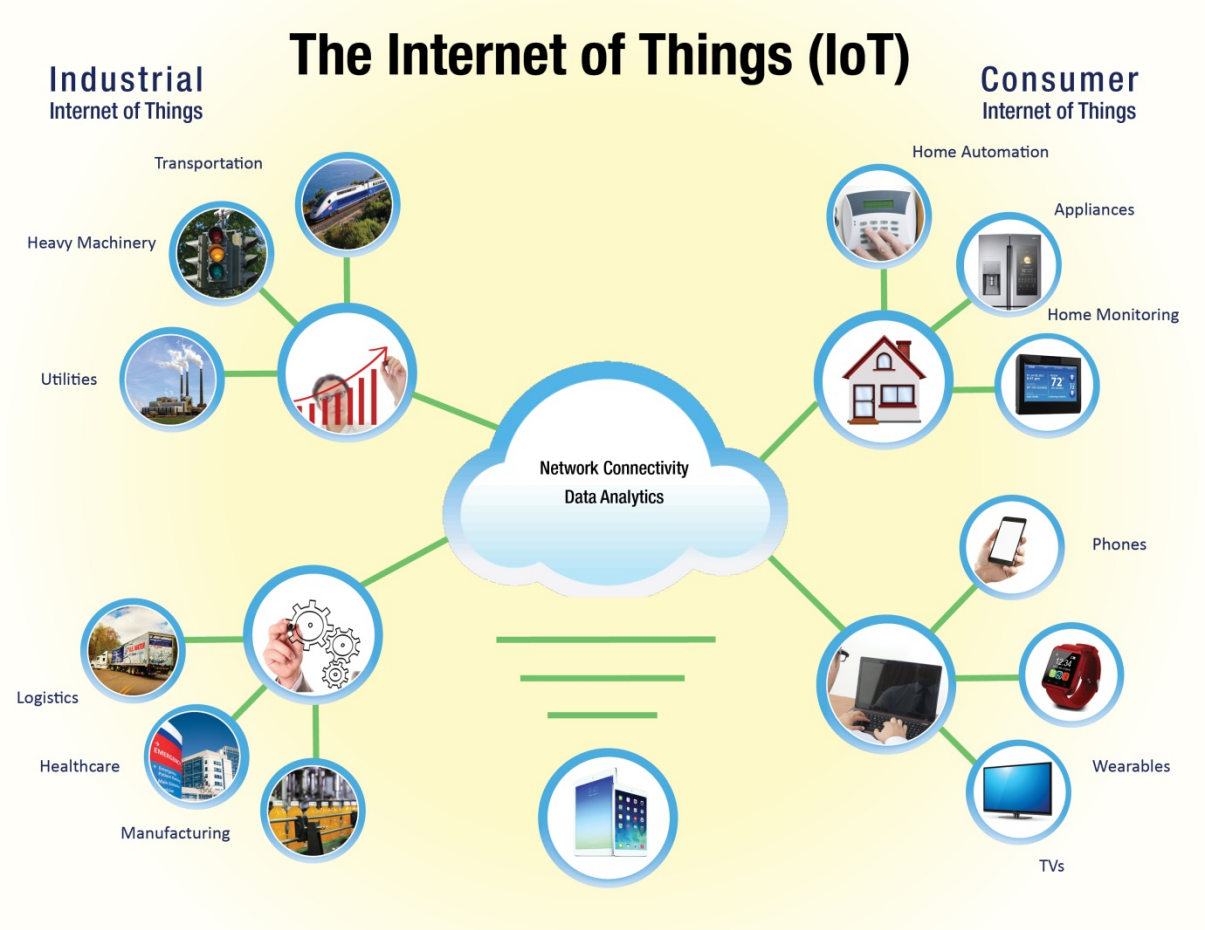


Figure 2: IoT Application Segments; Source: kuritaamerica.com

The major evolutionary change promised by IoT is the integration of networks that contain diverse devices and objects, making each or all of them directly accessible through the Internet as required.

[10] RFID Technologies: Supply-Chain Applications and Implementation Issues

The root of IoT can be traced to the Syntactic Web or the Internet of Content era when users' relationship with the Internet was limited only to the consumption of internet content. The Syntactic Web morphed into the Internet of Services epoch introducing e-Commerce and e-Productivity services such as online banking and Voice over IP (VOIP), heralding users' two-way interaction with the Internet.

Social Web or read-write web is the aeon with full interaction between the Internet and users. In this era every user can be a content producer and content is distributed and shared between sites. Some of the famous read-write web applications are Facebook, YouTube, Flickr, Twitter etc.

The Social Web metamorphosed into the present-day Semantic Web or read-write-execute web. In this epoch, computers can interpret information like humans via Artificial Intelligence (AI) and machine learning which help to intelligently generate and distribute content tailored to meet users' needs.[11]

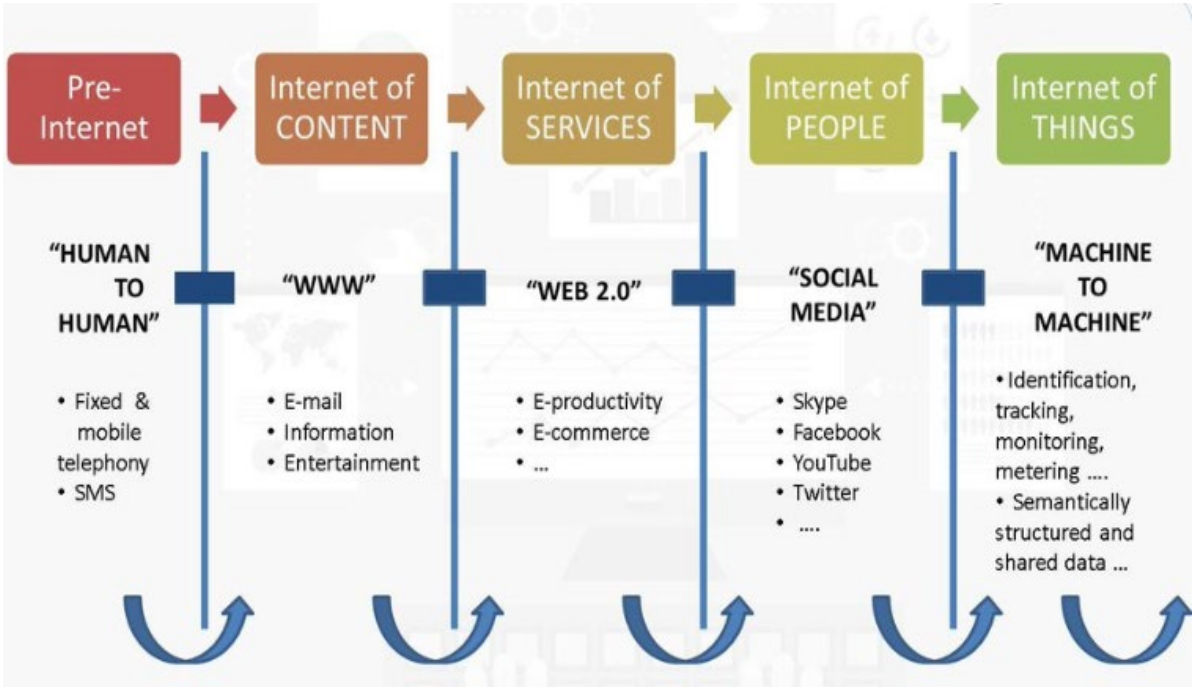


Figure 3: Evolution of the Internet of Things; Source: StartGrowthHack

[11] **Madurai Vivek**; Web Evolution from 1.0 to 3.0

3.2 IoT Ecosystem and Architecture

The ecosystem encompasses the rules, hardware, software, connectivity platforms and applications that make up an IoT System.[12]

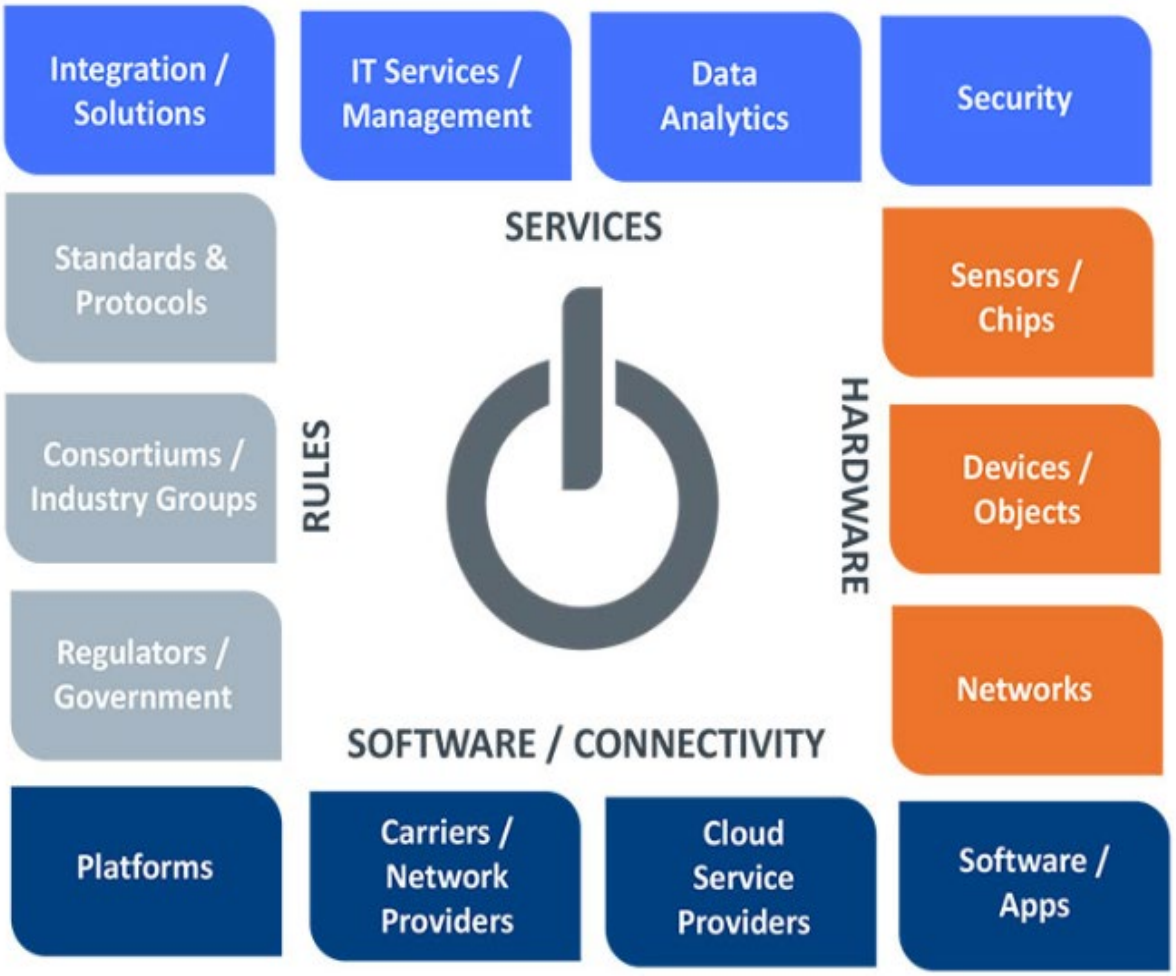


Figure 4: IoT Ecosystem; Source: Foundation of Computer Sciences

IoT Architecture

IoT Architecture describes a collection of devices equipped with sensors, actuators, and processors that communicate with each other to actualise a common purpose[13].

[12] **Foundation of Computer Science FCS.** *An Extended Review on Internet of Things (IoT) and its Promising Applications.*
[13] **Bhushan Aher;** A Look at IoT Architecture

IoT Enablers

While the idea of IoT has been in existence for a long time, a collection of recent advances in several technologies has made it practical. Some of these advances include:

- **Access to low-cost, low-power sensor technology**
  Affordable and reliable sensors are making IoT technology possible for more manufacturers.

- **Connectivity**
  A host of network protocols for the Internet has made it easy to connect sensors and other "things" to the cloud for efficient data transfer.

- **Cloud computing platforms**
  The increase in the availability of cloud platforms enables both businesses and consumers to access the infrastructure they need to scale up without actually having to manage it all.

- **Machine learning and analytics**
  With advances in machine learning and analytics, along with access to varied and vast amounts of data stored in the cloud businesses can gather insights faster and easier. The emergence of these allied technologies continues to push the boundaries of IoT and the data produced by IoT also feeds these technologies.

- **Artificial Intelligence**
  Advances in neural networks have brought natural-language processing (NLP) to IoT devices such as digital personal assistants and made them appealing, affordable, and viable for home use[14].

[14] What Is the Internet of Things (IoT)?; www.oracle.com

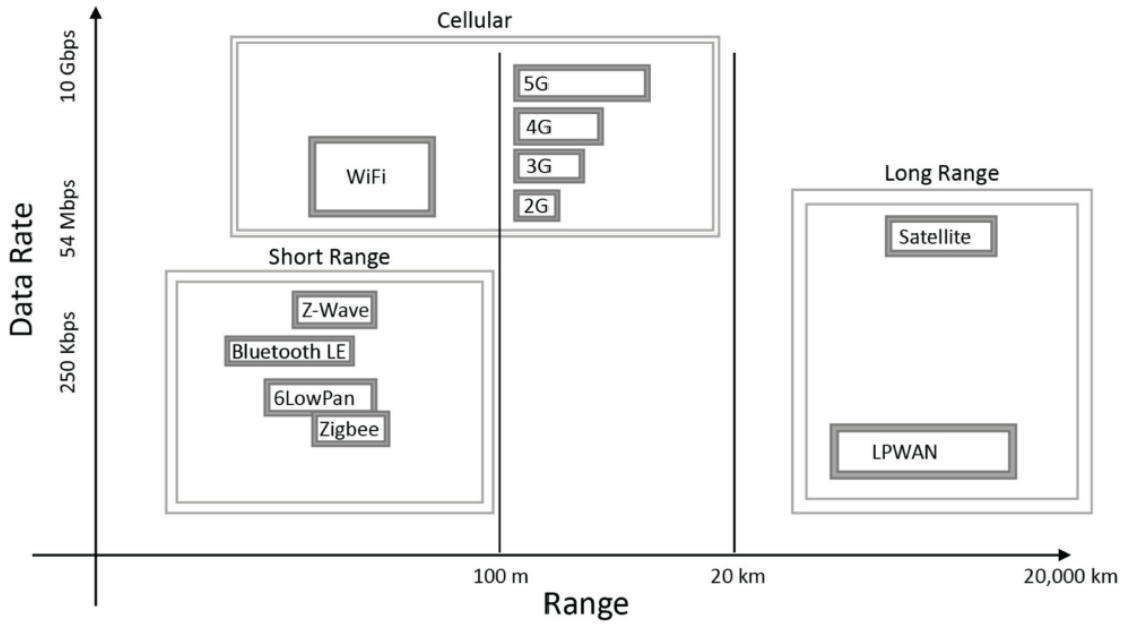
IoT Communication Technologies

Underpinning the IoT architecture are communication technologies including:

Protocol	Description	Advantages	Disadvantages
Zigbee	IEEE 802.15.4-based specification using mesh network topology and suitable for short- to medium-range	Long battery life (node sleep mode) > 65,000 nodes in a mesh network License-free frequency band	Short range (10–100 m) Incompatibility with other protocols Signal interference in 2.4 GHz band
Z-Wave	Mesh network protocol that uses low-energy radio waves and proprietary radio system	Devices are interoperable Suitable for low-power devices	Max 232 nodes in a mesh network Not suitable for high-power devices
LoRa (Long Range)	Long-range, low-power, and low-bitrate protocol that uses star topology and unlicensed ISM frequency bands	Long range (10 km) Low power consumption	Actual line-of-sight range of ~2 km Large bandwidth for data transmission
WiFi	IEEE 802.11 standards used for the wireless communications of short-distance local area networks	Broad device support Easy setup Inexpensive	Short range (~20 m)
Bluetooth Low Energy (BLE)	Wireless personal area network with low power consumption and cost	Broad device support License-free 2.4 GHz band Frequency-hopping reduces signal interference	Low bandwidth Short range (<100 m)
SigFox low-power wide area network (LPWAN)	Proprietary service tailored to IoT networks in a star topology operating on unlicensed ISM frequency band	Low power consumption Low-cost because the network and computing complexity is managed in the cloud	Not supported in all countries Susceptible to signal interference in some countries
Cellular	Network distributed in "cells" served by a fixed location transceiver. Most use star topology	Broad device support Available globally with large and growing infrastructure	Bandwidth can be limited due to network traffic High power

Table 2: Communication technologies

Figure 5: Communication technologies



Sensor Technologies

Alongside developments in internet technologies, technologies in sensors have also been evolving. The convergence of these two technologies, i.e. the Internet and Sensor Networks, is leading to new possibilities and visions[15].

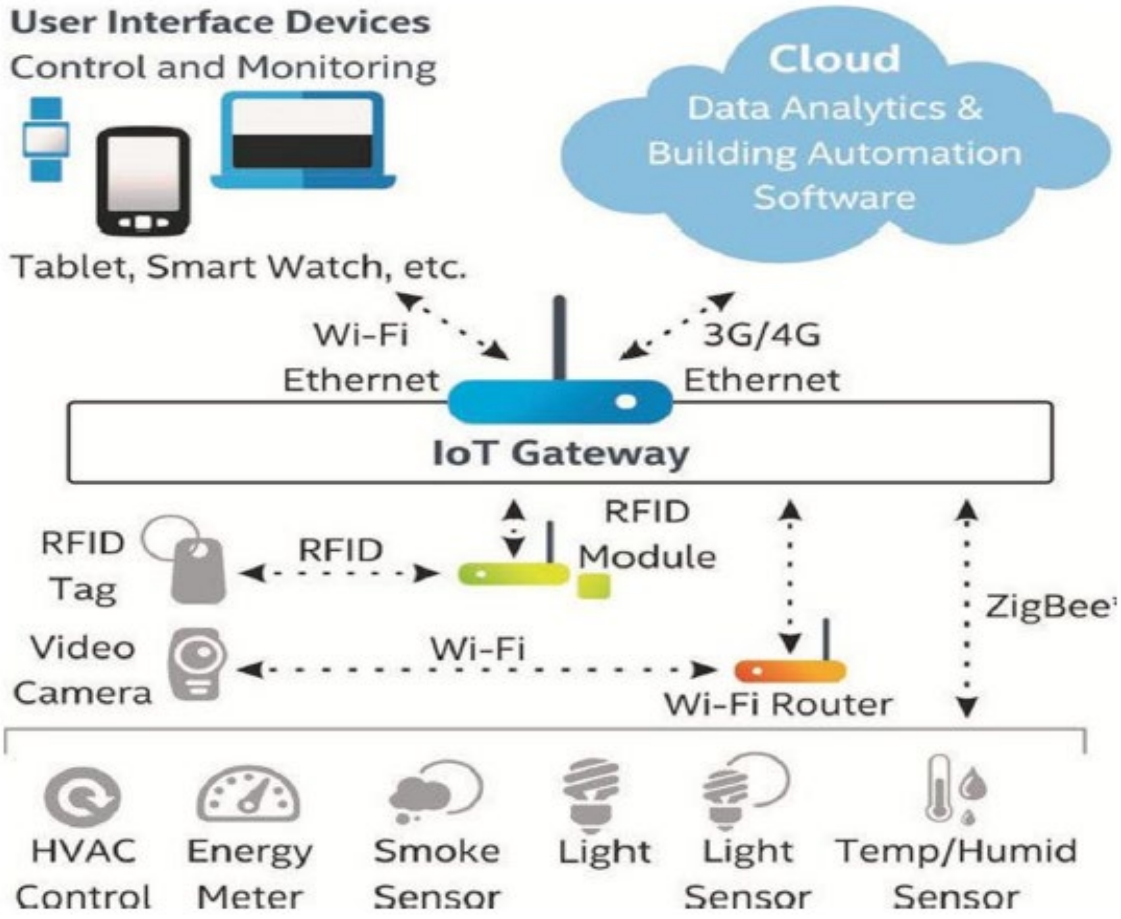


Figure 6: IoT Gateways; Source: Foundation of Computer Science

Critical hardware infrastructure for IoT includes Radio Frequency Identify (RFID), Near Field Communication (NFC) and Sensor Networks. RFID is a short-range communication technology where an RFID tag communicates with an RFID reader via radio-frequency electromagnetic fields[16]. Tags may contain different forms of data, but the data form most commonly used for IoT applications is the Electronic Product Code (EPC).

An EPC is a universally unique identifier for an object. These unique identifiers ensure that objects tracked with RFID tags have individual identities in the IoT.

[15] https://ieeexplore.ieee.org/document/5666553. 10.1109/POWERCON.2010.5666553.
[16] https://www.sciencedirect.com/topics/computer-science/radio-frequency-identification

Although RFID is not a new technology and its usefulness in terms of tracking objects has been well established, however, the tracking capabilities offered by RFID are generally understood to be the bedrock of the IoT. The benefits of RFID can be extended by making their data remotely accessible through the Internet.

A newer technology that builds on the RFID standard is Near Field Communication (NFC)[17] which is a short-range communication standard where devices can engage in radio communication with one another when touched together or brought into proximity to one another. Each NFC tag contains a Unique Identification (UID) that is associated with the tag.[18] The NFC technology is frequently integrated into smartphones which can exchange data with one another when brought together. NFC devices are also able to make connections with passive, unpowered NFC tags that are attached to objects.

Sensors are devices that monitor characteristics of the environment or other objects such as temperature, humidity, movement and quality. When multiple sensors are used together and interact, it is referred to as a wireless sensor network (WSN). Wireless sensor networks contain the sensors themselves and may also contain gateways that collect data from the sensors and pass it on to a server.

While sensors sense the state of an environment or object, actuators perform actions to affect the environment or object in some way. Actuators can affect the environment by emitting sound, light, radio waves or even smells. These capabilities are one way that IoT objects can communicate with people. Actuators are frequently used in combination with sensors to produce sensor-actuator networks.

One example of the use of actuators in such a network would be the use of a sensor to detect the presence of carbon monoxide in a room and the use of an actuator to produce a loud noise alerting people to the detection of the harmful gas. Thus, the combination of sensors and actuators can enable

[17] https://www.computerworld.com/article/2493888/a-short-history-of-nfc.html
[18] **Naser Hossein Motlagh,** Near Field Communication (NFC) A Technical Overview

objects to simultaneously be aware of their environment and interact with people.

An IoT device is a smart piece of hardware which has support for Internet connectivity and can interact with other devices within a network or over the Internet and can grant remote access to a user for managing the device as needed.

There are several IoT devices already in the Nigerian market including smartphones, smart refrigerators, smart watches, smart fire alarm systems, smart door locks, smart bicycles, medical sensors, fitness trackers, smart security systems, smart wearables etc. The communication technologies used in these devices are typically low energy wireless protocols such as Bluetooth, NFC, LTE, ZigBee, WiFi and so forth.

3.3 Objective One

What are the effective ways to encourage the use of IoT at all levels especially Government agencies, corporate bodies and individuals taking into cognizance existing resources such as frequency and infrastructure availability to increase broadband penetration levels in the country?

Key Findings

Using IoT allows organisations to fundamentally integrate sensing, analytics and automated control into their operations. Apart from cost savings, areas where improvements can be gained after adoption of IoT include: customer service delivery; innovation, processes and productivity; speed and agility of decision-making; competitive advantage and revenue; transparency and predictability of costs.[19]

In monetary terms, benefits of the IoT could be at $2trillion per annum where $1trillion could be based on cost reductions and another $1trillion could come from improved services.[20] These figures are outnumbered by an analysis which predicts that for the Auto Industry alone annual global savings of over $5.6trillion could be achieved by (semi-autonomous and autonomous) cars based on advanced connectivity technology.[21]

Within individual homes, there are wide varieties of IoT opportunities. Lighting, for example, can be dynamically adjusted via the Internet to provide a range of colours without changing bulbs or lamps. The lighting system can communicate with other IoT devices to learn the state of the weather and occupancy of various rooms and automatically adjust lighting accordingly. Power controls can adjust the timing and use of certain appliances to make the best use of energy. Tied into a smart power grid, the power controls can also respond to

[19] Peter C. Evans and Marco Annunziata; "Industrial Internet: Pushing the Boundaries of Minds and Machines"; http://www.ge.com/docs/chapters/Industrial_Internet.pdf
[20] Vodafone M2M Barometer 2015, p.3, 20.
[21] Morgan Stanley: Autonomous Cars: The Future Is Now; http://www.morganstanley.com/articles/autonomous-cars-the-future-is-now/

the power utility's request to lower energy usage during peak demand, lessening strain on the grid.[22]

The smart fridge can notify the owner of the expiring milk, and the need for more eggs. Shades can raise and lower with the time of day and the level of exterior light. Doors can lock and unlock automatically in response to the proximity and access permissions of the person or thing that is approaching.

The house is just one specific example. Capabilities are available across the broad range of application space noted in Figure 8 below - bringing automation and machine intelligence into people's lives as far as the Web brings information to people now.[23] IoT has vast potential to significantly change the way people live.

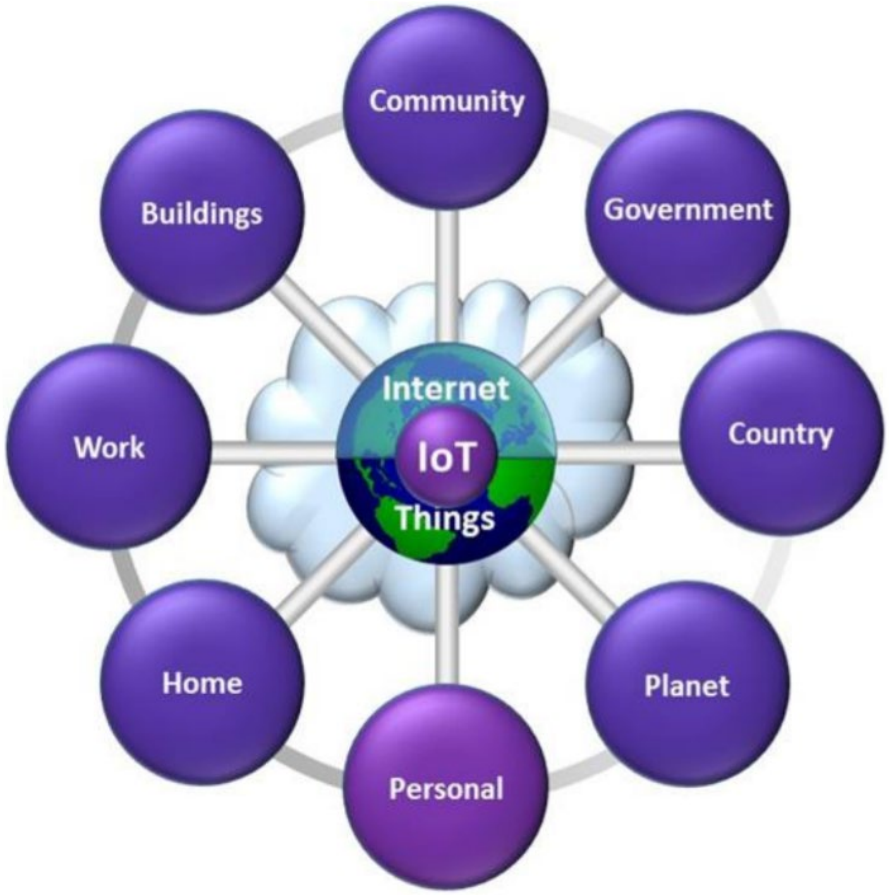


Figure 7: The Range of IoT Applications

[22] https://www.govtech.com/dc/articles/smart-grids-could-power-a-21st.html
[23] **U.S. Department of Defence,** *Policy Recommendations for the Internet of Things*

Smart Government – Innovative Public Service Delivery with the IoT

Federal, State and Local Governments have roles, processes and infrastructures that they need to execute and maintain, including roads, public spaces, emergency services, safety, security, healthcare, energy, public transport, garbage collection, public sewage systems and so on. These roles can be made more efficient by the IoT.

For instance, a State or Local Government might want to explore the opportunity to implement IoT-backed integrated closed circuit TV (CCTV) surveillance system to achieve goals such as increased safety and security of the lives and properties of residents. The low cost and pervasive nature of IoT can allow many tracking, inventory, control and data gathering activities to be accomplished with much less personnel labour involved and with significantly reduced intermediate processing and handling costs.

The IoT can support changes in the delivery of healthcare. Smaller sensors, smartphone assisted read-outs, big data analytics and continuous remote monitoring can enable new ways of delivering healthcare. Sensors now exist that can be swallowed with a pill and are being used to improve the accuracy of clinical trials in monitoring and managing patients' use of medication.[24] Such a digital health feedback system includes wearable and ingestible sensors that work together to gather information about medication-taking activity and rest patterns.

IoT devices can measure the amount of sleep a person has over time and monitor activity, blood pressure, glucose levels and heart rate which are the types of procedures medical practitioners carry out on their patients. Weight management can benefit too from regular monitoring using IoT-enabled devices.

[24] Sarah Murray, "How the internet of things can speed up health delivery", Financial Times, 6 April 2015, http://www.ft.com/intl/cms/s/0/8ad4d226-bdcc-11e4-8cf3-00144feab7de.html#axzz3XDyfx4Kw and a description of the technology at: http://www.proteus.com/technology/digital-health-feedback-system/

IoT Use in a Corporation

Imagine the supply chain management benefits of an extensive IoT implementation to improve visibility, physical security and even automate portions of an organisation's logistics processes. For example, at an NNPC tank farm, tank levels, temperatures and flow rates could be inexpensively and precisely monitored.

Inventory, usage and payments could be easily integrated with the back-end business systems. Perimeter security could be enhanced with more inexpensive cameras and motion sensors. Soil, water, and air quality could be continuously monitored for leaks or emissions. Tank and pipe corrosion and pump vibration could be monitored to enable fixes before impending failure. Transfer pumps and valves could be remotely operated from a variety of locations using apps on smartphones, keeping operators far away from the dangers of climbing tanks and potential fuel-related hazards.

IoT Opportunities in Telecommunications

The telecommunication sector is the poster boy of high-technology. This is largely driven by innovations around the Internet, smartphones and complexities in optimally managing the network infrastructures. IoT presents many interesting opportunities for the sector. These opportunities can drive both the bottom-line and top line bringing in more operational efficiencies as well as additional revenue streams.

A significant portion of a Telcos' infrastructure comprises large numbers of towers and supporting equipment distributed across vast geographical areas. A typical base tower site may have one or two generators for power backup, air conditioning gear, UPS, energy meters and so forth. Monitoring all these equipment for environmental protection, operational efficiency, physical security and predicting their failure in advance is an essential component to maintain network uptime.

Physical security is of paramount importance in remote places where there are costly equipment installed. An IoT-enabled intrusion detection system is a must. Added to this, there are pilferable consumables such as fuel and batteries used in the site which would benefit from an IoT-enabled resource consumption tracking system to ensure timely alerts to minimize losses.

Remote sites are also always under the threat of different kinds of hazards. The major one comes in the form of being vandalised by hoodlums, terrorists or even restive youths agitating for community or other quasi-political compensation. There are also the risks of fire, water and air pollution damage. IoT can help in detecting such issues as trespass, smoke, flooding or weather conditions and can assist in issuing control commands to either take preventive measures or shut down the system to avoid irreparable damages.

Being an IoT last mile connectivity service provider, Telcos can also tap into the Machine to Machine (M2M) ecosystem by playing the service provider role which opens up new and exciting revenue avenues just like the way in which value-added services boosted basic telephony and mobile services revenue streams for them.

IoT Implementation in a Secretariat or Agency HQ

A typical secretariat or Government agency HQ can be instrumented with thousands of network-connected sensors, from lighting to heating and air conditioning. These devices reduce energy and water use, monitor and control access, and enable heating, ventilation, and air conditioning (HVAC) systems to work collaboratively with fire and smoke detection devices to shut off and switch on as required.

Sensors can make building systems from HVAC to elevators more reliable, by predicting maintenance needs. Synthesizing the data between IoT sensing systems can enable safety improvements and help pinpoint hazards such as smoke or gas leakage. IoT data can also enable further efficiencies in the dynamic allocation of conference rooms and office spaces, location of car parking slots, vending of office supplies, and even delivery of packages.

To encourage the use of IoT at all levels especially Government agencies, corporate bodies and individuals it is illustrative to draw examples from other climes:

South Korea

Focussed on attaining a hyper-connected, digital revolution to underpin its IoT-driven economic development plan, the Korean Government set up the IoT Promotion Task Force. The main objective of the task force is to actualise its IoT promotion strategy with the objectives of developing and commercialising IoT-based business models and improving industrial competitiveness. In relation to spectrum, the Korean Government's plan is to see a total of 1GHz of spectrum freed by 2023, and have IPv6 infrastructure embedded into the country's subscriber network.[25] It targets the commercialisation of 5G mobile communications and for Gigabit Internet to achieve 90% of national coverage. It is promoting the development of low-power, long-distance and non-licensed band communication technologies for connecting objects in remote areas and has established an IoT test bed as a regulation-free zone.

Germany

To encourage this Industry segment, the German Government has launched the initiative called Small and Middle-Sized Businesses 4.0 - Digital Production and Work Processes, which aims at supporting small and medium scale enterprises with new information and communication technologies and the development of new business areas in the context of the IoT.[26] Several centres and agencies inform, qualify and support the companies under this initiative.

The German Government has also launched innovation clusters that are directly tied to the IoT. For example, the Cool Silicon innovation cluster in the south of Germany aims to develop low energy and energy self-sufficient processors and sensors.[27] Another innovation cluster called IT's OWL in the central part of Germany focuses on *Industrie 4.0* where the goal is to create

[25] Ministry of Science and ICT, South Korea
[26] http://www.mittelstand-digital.de/DE/Foerderinitiativen/mittelstand-4-0.html
[27] https://www.cool-silicon.de/

intelligent and autonomous industries through the use of robots.[28] Also in Germany, Microtec Südwest aims to develop microsystem technology focusing on the areas of smart production, smart mobility, smart health and smart energy.[29] A fourth cluster focuses on software for new industries. Each of the research clusters is tied to a large number of businesses, universities and research centres that combine to deliver the output.

Canada

The Canadian Government through its Centres of Excellence network has established a scheme called *Wavefront* which is focussed on the development of M2M and IoT companies in Canada by connecting them with critical resources, partners and opportunities.[30] Canada's largest province, Ontario, launched a pilot programme to allow for the testing of driverless vehicles on its roads. The province also pledged funding towards the Centres of Excellence Connected Vehicle/Automated Vehicle Programme, which brings academia and Industry together to promote and encourage innovative technology.

Denmark

The Albertslund Municipality in Denmark has an initiative called DOLL under a consortium comprising the private sector, academia and the municipality. The initiative focuses on energy efficiency and intelligent indoor and outdoor lighting solutions. The main aim is to create future LED-lighting solutions and generate jobs. An extension of DOLL is focused on testing and demonstrating Smart City solutions. The purpose is to look at different types of public services and make them smarter.[31]

Brazil

Pushing to become a leader in the IoT the Government of Brazil recently signed a decree establishing a National Action Plan for IoT focussing on four key verticals: cities, healthcare, agriculture and manufacturing. The decree identifies IoT devices and applications as value-added services rather than communications equipment thereby lowering the cost barrier to deploying IoT

[28] http://www.its-owl.de/home
[29] http://microtec-suedwest.de/en/.
[30] Transforming businesses through IoT innovation; http://www.nce-rce.gc.ca
[31] http://www.lightinglab.dk/UK/About-DOLL/

applications by exempting them from fees which apply to the inspection of telecommunication equipment in Brazil.[32]

The Government of Brazil also adapted its tax policies by introducing a special tax regime for M2M systems. The decree cut fees in SIM activations and an annual fee for SIM cards totalling a reduction of 80 per cent. The evolution of the number of M2M connections from when the decree took effect shows large growth of the special environmental sensor, car control system or home appliance category.

USA

Over $160 million in Federal funds is invested in research projects leveraging more than 25 new technology collaborations to help local communities address key challenges such as reducing traffic congestion, fighting crime, fostering economic growth, managing the effects of a changing climate, and improving the delivery of municipal services.

The United States Government also hosted a forum highlighting new steps and brainstormed additional ways that science and technology can support municipal efforts. The forum included the creation of test beds for IoT applications and big data analytics, with the intention of helping United States companies to become global leaders in this field.[33]

On-going initiatives include new grants to build a research infrastructure for Smart Cities by the National Science Foundation and the National Institute of Standards and Technology; proposed investments to unlock new solutions in safety, energy, climate preparedness, transportation, health and more, by the Department of Homeland Security, Department of Transportation, Department of Energy, Department of Commerce, and the Environmental Protection Agency; and more than 20 cities participating in major new multi-city collaborations that will help city leaders effectively collaborate with universities and Industry.

[32] https://www.datainnovation.org/2019/08/brazil-pushes-to-become-leader-in-the-internet-of-things/
[33] https://www.whitehouse.gov/the-press-office/2015/09/14/fact-sheet-administration-announces-new-smart-cities-initiative-help

France is financing embedded systems and IoT from a $450 million fund for digital development.[34]

Nigeria

Many Nigerian citizens and businesses remain excluded from the digital ecosystem as a result of limited access to broadband and the affordability of adequate devices such as smartphones and computers to fully utilize the Internet. Improved digital connectivity can only achieve the desired transformational impact on economic opportunity and inclusive growth if combined with improvements in digital skills and literacy as well as digital support to start-ups and existing businesses. With such capabilities, the Nigerian economy can harness digital data and new technologies, generate new content, link individuals with markets and Government services and roll out new and sustainable business models.

While other demand-side barriers relate to digital illiteracy, lack of local content and low electrification rates, for Nigeria to gain the critical number of the Internet subscribers needed to build its digital ecosystem and kick-start its digital transformation, innovative solutions and strategic interventions and investments will be required. The Government needs to promote the deployment of networks in underserved areas, support the reduction of broadband costs, provide additional complementary public access and stimulate demand by addressing the digital economy foundations with an ecosystem approach.

The ecosystem approach involves building the key foundational elements of a digital economy. These foundations are synergistic and require the collaboration of both the public and private sector. They include:

- **Digital Infrastructure** - anchored on good and affordable internet connectivity;
- **Digital Platforms** - for Government to offer citizen-facing Government services and commercial firms to offer their array of products and services;

[34] http://www.usine-digitale.fr/article/encore-450-millions-d-euros-pour-financer-des-projets-numeriques.N314624

- **Digital Financial Services** - to enable individuals and businesses to conduct transactions electronically;
- **Digital Entrepreneurship** – to create an ecosystem that brings the digital economy to life with new growth-oriented ventures and the transformation of existing businesses for growth and enhancement of competitiveness and productivity; and
- **Digital Skills** – to grow the digitally savvy workforce that will build the robust digital economy.

When asked what they consider the most important factor to accelerate the adoption of the IoT 32% of Industry stakeholders said Interoperability between devices would be their most important factor, while 18% chose Ease of Development of the IoT implementation. Surprisingly, only 5% considered Energy Consumption as a factor with 8% saying that the wider adoption of the IoT by the Public Sector would be a definitive boost. The Need for Data Privacy Policy and Connectivity Standards were rated as important by 10% and 12% of respondents respectively.

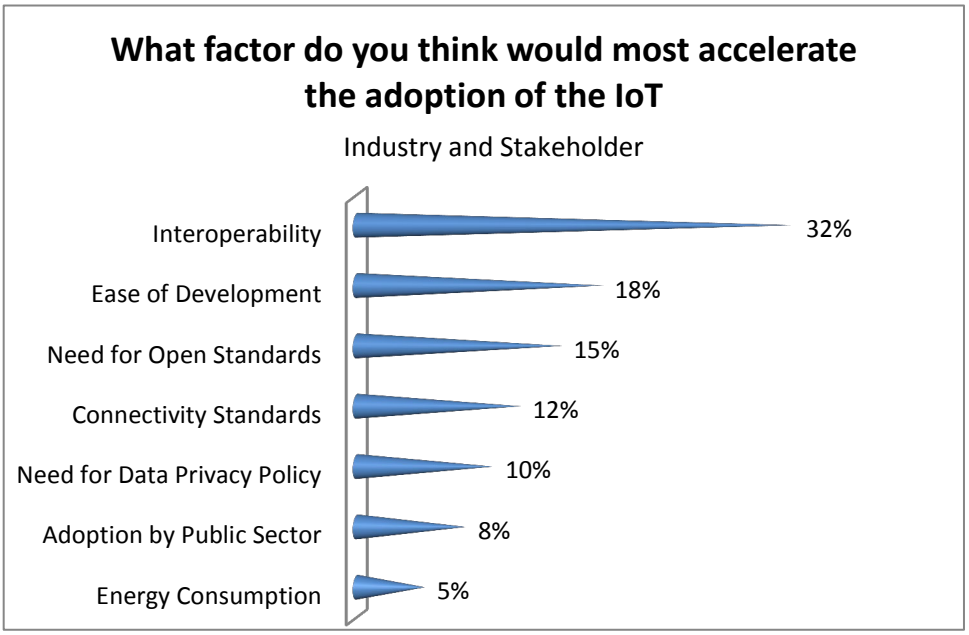


Figure 8: Industry and Stakeholder Response on What Factor would most Accelerate IoT Adoption

3.4 Objective Two

What cost-efficient frameworks and models can be deployed for the setting up of technology incubation centres in Nigeria which will ultimately help promote the development of IoT devices and drive its development and deployment?

Key Findings

From the private sector, the infrastructure and support ecosystem for digital entrepreneurs are tangentially growing. There are over 100 digital hubs, incubators, co-working spaces and accelerators across the country and the numbers are on the rise. However, they face significant constraints that hinder their effectiveness. Nigeria has also attracted several multinational companies including Google, Microsoft, and Facebook which have set up their own incubators/accelerator programs mostly in collaboration with indigenous organisations.

Most of the digital hubs provide valuable co-working spaces to start-ups, but they operate in isolation, have limited funding and are invariably all located in the major cities of Lagos, Abuja, Kaduna and Port Harcourt. Digital entrepreneurs need several rounds of support to qualify for private investments, which is an additional burden on hubs and accelerators, most of which do not have their own sources of adequate funding.

Linkages to academia are limited, with only a handful of university-based hubs. The lack of coordination between the various ecosystem actors limits their effectiveness and few digital entrepreneurs are satisfied with the level and quality of services.

The study identified the existence of thirty-seven (37) Federal Government-owned Technology Incubation Centres (TICs) dotted across the country. The National Board for Technology Incubation (NBTI) is the Government agency with the mandate to oversight these incubation centres.

The objectives of the Nigerian technology incubation program are to:

- Facilitate the establishment and coordinate the activities of technology incubation centres and science & technology parks which are designed to nurture new technology-based start-up businesses nationwide;[35]
- Sensitize all stakeholders for the establishment, supervision and regulation of technology incubation centres;
- Provide institutional infrastructure and mechanisms for the development and commercialization of R&D outputs and inventions;
- Involve all relevant stakeholders in the establishment of technology incubation centres across the country;
- Source and develop commercially viable indigenous and foreign technologies;
- Source funds for the implementation of its incubation programmes;
- Source entrepreneurs and investors for the commercialization of chosen technologies;
- Ensure the competitiveness of the products of its programmes through value-added service support and effective linkages to knowledge providers to ensure continuous injection of innovation in materials processing and/or equipment;
- Ensure efficient and effective performance leading to the accelerated growth of entrepreneurs in the programme;
- Subsidize all services provided by the technology incubation programme to reduce the overhead burdens of start-up enterprises;
- Provide a post-incubation survival scheme for the enterprises who graduated from the programme;
- Promote the growth of the private sector through the creation of competitive SMEs as the engine of growth of wealth creation, employment generation and poverty reduction;
- Encourage value re-orientation to promote hard work, transparency and accountability in business operations;
- Interface with research establishments and tertiary institutions for the commercialization of their R&D outputs;
- Promote Nigeria's indigenous potentials through value-added and technology-related activities; and
- Create enabling environment for effective linkage amongst technology providers, entrepreneurs and capital.

[35] https://www.nbti.gov.ng/mandate

The expected benefits of the Technology Incubation Program include:

- Promotion of indigenous industrial development by strengthening the nation's industrial base at the SMEs level;[36]
- Commercialisation of R&D findings from research institutes, universities and similar institutions;
- Diversification of the economy through the development of SMEs in manufacturing and services;
- Linkage with big suppliers, thereby reducing dependence on imports;
- Creation of jobs and thus a reduction in unemployment in the country; and
- Contribution to the national revenue generation through the payment of VAT, Excise Duty and Tax.

Technology incubation as a mechanism for managing risk outside of standard R&D processes and metrics should aim to produce successful businesses that will leave the program on time, be financially viable and freestanding.

The study's preliminary findings are that:

- The Federal Government-owned TICs have had a weak socio-economic impact on job creation, wealth creation and industrial development in Nigeria. The reverse is the case for the BRIC nations, (Brazil, Russia, India, and China) adopted as comparative models, where TICs have impacted positively on employment and economic development;

- There is glaring inadequacy in the number of TICs in the country with nearly all of the existing ones located mainly in State capitals. This inadvertently creates an urban-rural divide between innovators whose locations are outside the capital cities;

[36] https://www.nbti.gov.ng/mandate

- There is palpable paucity of structured support services available to micro small and medium scale enterprises (MSMEs) especially those in the rural areas;

- The existing Federal Government-owned incubators have weak operational structures and lack measurable targets and objectives, compounded by inadequate funding;

- There is insufficient involvement by the private sector, third sector and non-Government organisations as more of them are required than are currently playing actively in Nigeria's technology incubation space; and

- Most of the well-known multi-national companies doing big things in Nigeria especially related to hardware and software appear to short-change prospective Nigerian technologists and budding entrepreneurs by operating their TICs in other countries outside Nigeria.

3.6 Objective Three

What are the new revenue streams that can be used to stimulate the growth of Nigeria's tech ecosystem?

Key Findings

Globally funding for business start-ups is invariably always fraught with difficulties. It is even more so here in Nigeria where the regulatory environment remains challenging and creates supply-side barriers to credit as willing lenders are unable to meet the credit demands of qualified borrowers due, more often than not, to legal issues rather than capacity or technological ones. There are too many licenses required and many bureaucratic hurdles to scale before an entrepreneur can participate in the funding space. There is also lack of clarity in the regulatory environment and regulators are not as proactive in catering to the fast-paced nature of the Industry.

Current legislation prohibits private limited liability companies, which is the most common form for digital start-ups, from: (i) inviting the public to subscribe for any shares or debentures of the company or deposit money to it; and (ii) having more than 50 shareholders.[37] In addition, the Investment and Securities Act (ISA) bars all invitations to the public to acquire or dispose of the securities of a corporate entity or to deposit money with any corporate entity for a fixed period or payable at call, whether bearing interest or not, unless the body corporate concerned is a public company. Therefore, only public companies in Nigeria may offer their shares to the public.

There is a lack of clarity regarding the legitimacy of new investment vehicles such as crowdfunding in Nigeria. These inadequate policy and regulatory frameworks leave digital start-ups struggling to attract funding.

Fortuitously, the private sector-led business start-up infrastructure in Nigeria is expanding significantly. Current initiatives and players in that space include many non-Governmental organisations and private sector operators, a selection of which is listed in the table below.

[37] Companies and Allied Matters Act (CAMA) 2020

Scheme/Programme	Area of Impact
Youth Entrepreneurship Support Programme	An initiative by the Federal Government through the Bank of Industry to empower youth entrepreneurship;
TEF Entrepreneurship Programme	Runs a funding cycle every year for entrepreneurs aged 18 years and above who have an early-stage business. Supports and promotes entrepreneurs and leaders across the continent;
Africa's Young Entrepreneurs Empowerment Nigeria (AYEEN)	Provides start-up funding across several stages for those who meet its eligibility criteria;
LeadPath Nigeria	Provides seed capital for short, medium and long-term funding to SME start-ups in high-growth technology areas such as software, web and mobile technologies;
Growth Capital Fund	Powered by CCHub, is a social innovation fund aimed at driving socially-conscious businesses to build Nigeria's next generation of infrastructure;
Ventures Platform	Provides all-series funding for product designers who have built something exceptional for their markets;
Lagos Angel Network	Powers DealDay events where start-ups get to pitch in front of several potential funders dubbed angel investors;
The U.S. African Development Foundation	Supports African entrepreneurs by providing seed capital for their businesses. The Foundation gives technical support to

	youth-led enterprises;
Bank of Industry	BoI has different fund schemes, for different categories of business;
Shell Livewire	A social investment platform that helps young entrepreneurs in Nigeria to make their dream of starting their own businesses a reality;
Dangote-BoI Fund for Small Businesses	A partnership between Dangote Group and BoI to set up enterprises and support entrepreneurs in Nigeria;
The Government Enterprise and Empowerment Programme (GEEP)	Scheme established to provide interest-free loans to businesses in Nigeria;
GroFinFUND	A development financier body that supports and finances growing businesses across Africa;
LoftyInc Capital Management	Focuses on early-stage Africa-facing enterprises that leverage technologies to create social impact and tackle big problems; and
Business Development Fund For Women (BUDFOW)	A project of the Federal Ministry of Women Affairs and Social Development (FMWASD) but managed by BoI.

Table 3: Organisations Active in the Start-Ups Funding Space

The IoT Revenue Streams

The IoT is indeed a hugely exciting marvel. It has the potential to create a world where everything is connected. While there are numerous agile start-ups emerging from this fertile ground, the IoT offers an unprecedented opportunity for traditional organizations to utilise IoT applications to reshape their business models, fully optimise their performance and open up new revenue streams through wide-scale, intelligent solutions.

The four distinct IoT revenue models that are emerging are outlined below.

Revenue Model	Description / Target customers / Success Factors
Hardware Premium	Simplest model where organizations charge a price-premium for the product's connected features. Here, organizations add connectivity options to an existing or new product and offer remote device management in the form of mobile apps. This basic level of connectivity and control enables organizations to charge a premium for their product. From a consumer perspective, a key driver for buying hardware premium products is the novelty factor involved in controlling hitherto standalone devices. Hardware companies that want to differentiate themselves. Enhanced value delivered over traditional products.
Service Revenue	In this model, organizations convert what has been a traditional product into a service by tying in a recurring pricing model for specific features. The service model offers a recurring revenue stream and, more importantly, creates a relationship with the customer long after they have purchased a product. A vehicle manufacturer, for example, may choose to offer security features, maintenance assistance and navigation tools in their new vehicles for a set subscription fee. Companies that have products with high customer engagement such as vehicles. Having multiple subscription options at varying price points including free.

Data Revenue	IoT devices generate large volumes of sensor data. For many organizations, the ability to capture, package and sell this data offers a potential revenue stream. Once this data has been aggregated and anonymized, organizations can choose to sell it raw, package insights from it or monetize it using advertising. In this model, organizations generate revenues by selling packaged data gathered from sensors. Companies that are in a position to collect significant amount of data from customers. Managing customer privacy and staying compliant to regulations.
Ecosystem Building	In this model, organizations create a platform where they ideally make money from both other product vendors and end consumers. In an ecosystem model, the focus is not on selling a product or a service but on providing a shared platform to other players in the ecosystem – hardware manufacturers, software developers, service providers and the like. In such a model, the platform promoter ideally makes money from both end customers as well as other platform users. Platform users pay the promoter for listing and the promoter also gets a share whenever a product is sold to the end customer on the platform. A shared platform brings multiple benefits to participants. For instance companies that have a wide range of technology. Ensuring the platform is equitable to all stakeholders and not just platform promoters' products.

Table 4: IoT Revenue Models

3.7 Objective Four

What policy guidelines can be suggested to improve security and assuage privacy concerns in using IoT?

Key Findings

As IoT enters its defining moment, it remains an area of tremendous promise for many industries. Taking steps to ensure that proper policies, guidelines, procedures and parameters are in place is essential for effective and transformative IoT implementation.[38]

While the specifics of an IoT policy will vary between industries and organizations, the presence of a policy itself that is readily accessible and widely understood should not.

At a basic level, policies must prepare an organisation to react to security incidents and ensure appropriate diligence concerning integrity, confidentiality and safety of IoT devices and solutions.

There are four key areas where organizations must establish guidelines and have set policy tenets that minimize the risks and maximize the benefits of IoT.

	Area	Impact
1	Governance	Effective governance policies strike a thoughtful balance between participation, accountability, access, privacy, coherence and safety without constricting innovation and creativity;
2	Security	It is essential to build a system with security in mind from the start, with focus and consideration on the protection of the public and resilience to attacks rather than including security in hindsight;

[38] **Julia Kanouse;** Developing an IoT policy; IoT in Business: Deploy a Successful Connected Enterprise

3	Data management	Any IoT system should be open and transparent about the ownership and retention of data; transfer of data and the chain of custody of data; and
4	Privacy	IoT deployments must protect and respect the privacy of individuals and the confidentiality of the enterprise/agency; balance needs to be established between transparency and access rights.

Table 5: Key Policy Areas

Key tenets for Government and corporate organisations to consider while constructing policy guidelines are listed here:

- Each IoT acquisition must be supported by a business case.
- Each IoT implementation and associated data streams must be supported by a security and privacy risk assessment.
- IoT data must be encrypted at every point, where costs are commensurate with risk and value.
- IoT networks must be monitored to identify anomalous traffic and emergent threats.
- IoT data will be fed to analytics capabilities and cross-correlated to get the maximum utility from the information.
- IoT devices and Logical Processing Area Networks (LPANs) must be connected to as small a controlled network segment as feasible, rather than having unfettered access to the full IP network.
- IoT devices must only be acquired through approved contract channels.
- IoT device supply chains from the factory to installation must be actively managed.
- Network operations must be able to verify the network identity of IoT devices and track the provenance of the information they provide.
- Network operations must be able to detect, isolate and remove unauthorized IoT devices.
- Organisations must establish policy and guidelines that establish internal responsibilities and controls.
- Government must monitor the execution of responsibilities and monitor the effectiveness of controls.

3.8 Objective Five

Are there regulatory incentives for deployment of IoT by corporate bodies such as utility companies, logistics, and IoT friendly service providers amongst others?

Key Findings

Given the potential economic benefits of IoT, growth will be accelerated if the Government can give early clarity on what is regulated or unregulated and permitted or prohibited. A clear regulatory framework will engender informed decision making for investors and accelerate the development of the IoT ecosystem and make it more sustainable.[39]

Federal and State Governments in Nigeria would help entrepreneurship by promoting incentive-based regulations that are designed to induce changes in the behaviour of individuals or organisations to produce environmental, social, or economic benefits that would otherwise be prescribed by legislation.

An approach that incentivizes end users to adopt the latest equipment, software, training and operating protocols would give policymakers the support they need to enforce current and encourage new regulations that tie back to common priorities.

Investors look for investments that can create the most value for their shareholders. In cases where cyber security-driven modernization investments are not the best choice regarding shareholder value, the Government should consider Federal incentive mechanisms that encourage such investments when they are in the public interest.

These mechanisms come in many forms. Most simplistically they could take the form of tax incentives or abatements. Investments in improving cyber-security in some regulated sectors would come with tax write-offs or tax holidays.

[39] **Arthur D. Little;** IoT Policy; www.adl.com/IoT_Policy

Other, more complex incentives include measures such as rebates for specific investments through federally funded programs, price caps and performance-based incentives tied to specific cyber-security related goals that can be considered. The Government can assist enterprises to acquire modern industrial automation and control systems and solutions by way of grants, loans or duty waivers to help cushion the costs. In this scenario, the companies receive funding to reinvest in the latest technology, staff training and liability management initiatives.

Regardless of how the incentives are funded and structured, the scenario will be mutually beneficial for consumers, companies and the Government alike. As a collaborative multi-stakeholder Industry, the Government should explore a balance of regulations, standards and incentives. On this, the challenge for the Government will be twofold: (a) to avoid falling further behind technological change; and (b) to avoid disproportionate and potentially harmful regulations.

The Federal Government holds several important levers that if utilized properly can effectively push the Industry towards effective self-regulation. The sector is capable of coming up with clear accountability and strengthened information sharing etiquette among IoT manufacturers, retailers, resellers, integrators, service providers and even consumers.

The objective of regulation is to define obligations and clarify liabilities. Regulation, as an incentive, limits the possibility to be subject to punitive fines and protects the reputation of all parties involved. Regulatory incentives can come in several ways including knowledge and technical support, tax breaks, reduced tariffs on imported equipment and interventions where necessary.

As most IoT business models rely on data collection and sharing, it is necessary to have a regulation that requires the integration of privacy-by-design and privacy-by-default into IoT systems.[40] The regulatory incentive of such a requirement is that it secures consumers' trust in the products and services covered by the regulation.

Safety is another important parameter in IoT. In Industrial Internet of Things, safety-functions are mainly managed by software and a vulnerable IoT system

[40] Data Protection Working Party (2014); *Recent Developments on the Internet of Things.*

is potentially unsafe and can expose its users to injury or even death. It is imperative therefore to have regulation in place that factors the concept of safety-by-design into IoT systems. This has the regulatory incentive of securing critical IoT systems and limiting their owners' exposure to penalties and losses should they fail.

To mitigate the associated risks of IoT security breaches or as part of their CSR, corporate organisations should be encouraged by regulation to integrate security for IoT as a central part of their corporate strategy.

Many firms engaged in IoT development and businesses argue, however, that the global nature of IoT services and the need to promote innovation in the private sector require a light-touch regulatory approach. Multinational firms advocate for more transparent, predictable, and technology neutral laws and regulatory requirements to avoid impeding the pace of IoT innovation and economic growth. The[41] can be mentioned as a good example of a properly crafted policy framework as it enshrines the principles of predictability and technological neutrality. Its pro-competition regulatory approach promotes investment while imposing proportionate and appropriate regulatory measures.

To buttress that the European Regulatory Framework for Electronic Communications can be used as a regulatory model for promoting IoT innovations, it is illustrative to attempt a review of its key elements and provisions.

Review of the EU Regulatory Framework for Electronic Communications

The EU Regulatory Framework for Electronic Communications paves the way towards strengthening the European electronic communications market by revising rules to ensure more effective competition and better rights for consumers. It enables the market to become more competitive, generating investment, innovation and growth in all EU Member States. It also helps to midwife new communication services affording consumers benefits from lower prices, better quality and increased transparency.

[41] The framework is intended to raise standards of regulation and competition across all EU Member States' communications markets

The EU framework constitutes the basis for a supportive and consistent regulatory environment reinforcing competition while enhancing incentives to invest. Its provisions on freeing radio spectrum resulted in improvement on the availability of new wireless services, including wireless broadband at reasonable costs to the consumers.

In summary, the framework seeks primarily to:

- Strengthen competition in the electronic communications sector
- Stimulate investment
- Foster freedom of choice for consumers and enable them to benefit from innovative services, quality and lower rates.

The Framework consists of these five Directives:

- Access and Interconnection Directive (AID) (2002/19/EC);
- Authorisation Directive (AD) (2002/20/EC);
- Framework Directive (FD) (2002/21/EC);
- Universal Service Directive (USD) (2002/22/EC); and
- Data Protection Directive (DPD) (2002/58/EC).

1. Access Interconnection Directive (AID)

Deals with wholesale relationships between providers of networks, services and associated facilities; places general obligations on operators to negotiate interconnection. It sets out National Regulatory Agencies' (NRA) responsibilities and the limits of their discretion to ensure operators' obligations related to access or interconnection are met.

2. Authorisation Directive (AD)

Abolishes existing licensing regimes and replaces them with general conditions or obligations. Providers of electronic communications networks and services are no longer required to obtain explicit approval before they can offer services.

3. Framework Directive (FD)

- Sets out the overall framework for regulatory decisions, including objectives and principles which must be taken into account when making regulatory decisions;
- Sets out the principle that market reviews must be carried out to establish the level of competition in a market before any regulation is imposed. Regulation can only be imposed if a market is found not to be effectively competitive;
- Requires Commission-wide consultations before taking decisions and implementing procedures to ensure that the objective of harmonisation across Europe is met.

4. Universal Service Directive (USD)

- Establishes the procedure for designating providers of universal services;
- Specifies a minimum set of services that operators must provide. Gives details of specific obligations that may be imposed on providers in retail markets (as the AID does for wholesale markets). The USD also sets standards for consumers' contracts with telecoms providers, number portability and procedures for providing consumers with an out-of-court dispute resolution process.

5. Data Protection Directive (DPD)

Sets out how telecoms users' personal data can be used to ensure consumers' right to privacy.

The Framework simply simplifies and harmonises more than 20 existing EU Regulations and Directives governing electronic communications networks, i.e. transmission systems which permit the conveyance of signals by wire, radio, optical or other electromagnetic means including satellite networks, fixed and mobile terrestrial networks, electricity cable systems, radio and television broadcasting and cable television networks, irrespective of the type of information conveyed; and, electronic communications services consisting of the transmission of signals over these networks and associated facilities.

The Framework covers all aspects concerning both the substance of the regulation of electronic communications networks and services and the procedures needed for its implementation including the:

- Assignment of radio frequencies and numbering resources
- Strategic planning, coordination and harmonisation of radio spectrum in the European Union;
- Rights of way for the roll-out of networks and associated facilities;
- Sharing of network elements and associated facilities;
- Security and integrity of networks and services;
- Standardisation designed to promote the harmonised provision of electronic communications networks and services and associated facilities and services;
- Interoperability of digital television services;
- Control over powerful companies on the market and the procedure for the consistent application of solutions;
- procedures for defining and analysing relevant markets;
- Settlement of disputes between undertakings providing electronic communications networks or services, including the Regulation on cross-border disputes.

The Directives update existing concepts with regards to the already converging telecommunications, digital broadcasting and Internet Industries and simplify the rules for market entry, with new authorisation rules across the EU that remove the requirement for individual licences and provide NRAs with tools to cope with evolving future technology and market changes.

The Directives reduce regulation, stimulate competition and create a clear and consistent regulatory framework across the EU for all telecoms operators.

3.9 Objective Six

How can IoT improve the economic status of Nigeria?

Key Findings

The Information Communications Technology in general contributed 17.83% to Nigeria's total real GDP in Q2 2020, 20.54% higher than its contribution a year earlier and the preceding quarter, in which it accounted for 14.07%.[42] According to NCC, the contribution to Nigeria's GDP by the telecommunication sector alone has risen from 8.5% in 2015 to 14.35% as at September, 2020 amounting to ₦2.27trillion.[43]

Some estimates posit that IoT could add roughly $15 trillion to global GDP with a cumulative economic impact of $3.9 trillion to $11 trillion per year by 2025.[44]

The wireless capabilities of smartphones, from NFC to low energy Bluetooth, and their pervasive adoption in such a short timeframe mean that the devices to read and interact with the IoT are already available at scale. In the subset of IoT that are consumer-facing, smartphones play an important role in bringing the technology to a broad range of consumers.[45]

In a broader sense, the IoT brings skills opportunities in several areas particularly data curation, open data, big data analytics and cloud computing. For each of these areas, there is a need to identify the skills required by the workforce, align the curricula to support the development of these skills and promote training opportunities through a combination of formal and informal methods.

Societies influenced under the IoT will create an impetus to change traditional education from one, which in many ways is still designed to fill traditional

[42] The National Bureau of Statistics; Nigeria's Gross Domestic Product Report, Q2 2020
[43] https://economicconfidential.com/2020/10/ncc-contributes-n2-27trn-nigeria-gdp/
[44] https://www.consultancy.uk/news/2783/iot-to-add-up-to-111-trillion-to-global-economy-by-2025
[45] http://venturebeat.com/2013/01/02/internet-of-things-via-smartphone/

workforce or assembly line jobs, to one that encourages entrepreneurship, innovation and invention. The Federal Government, State Governments and policymakers need to understand how to adapt the education system to align with Industry requirements.

Upskilling programmes covering both generic and technical skills should adjust displaced workers ensuring that the supply of new skills keeps pace with the new demands in IoT related sector such as sensors, robotics, data analytics and software development.

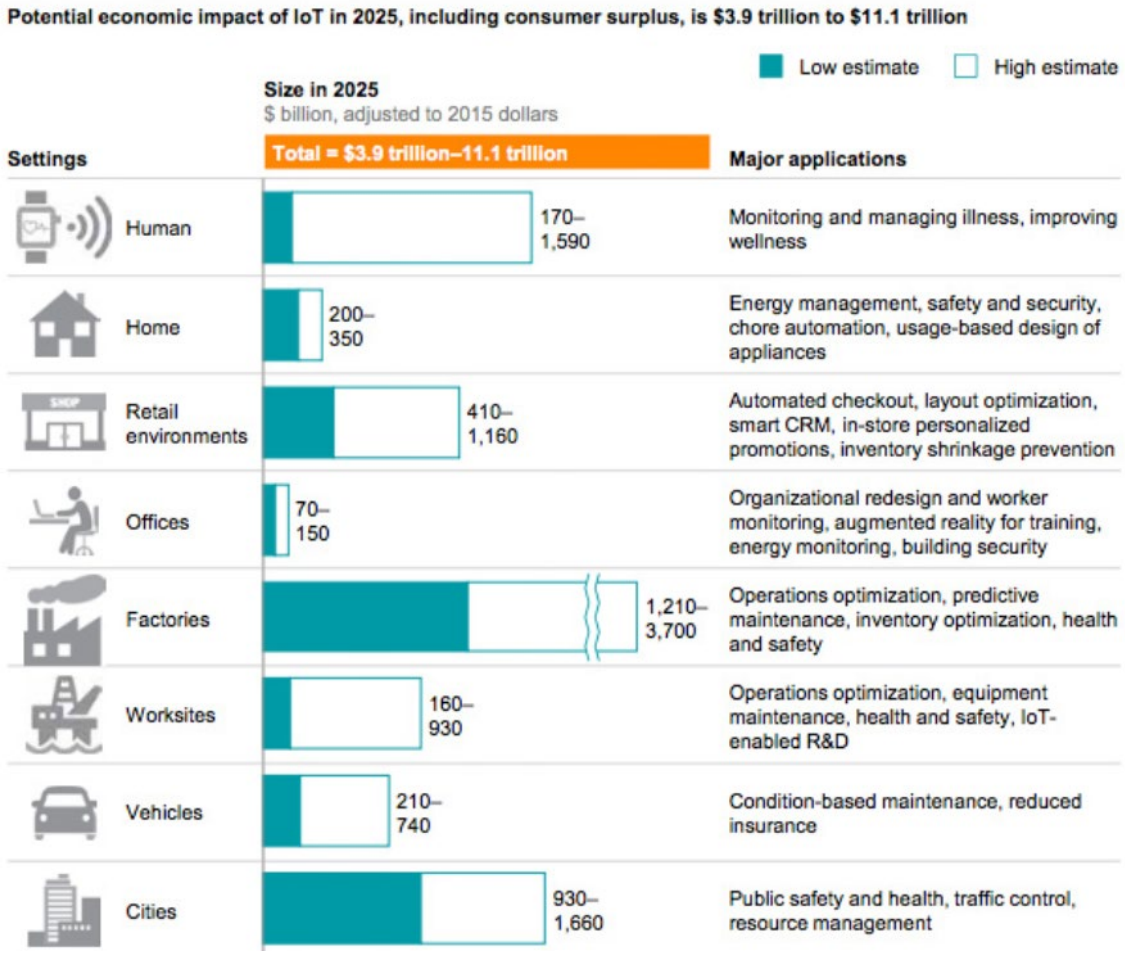


Figure 9: Projected Economic Impact of IoT; Source: Mckinsey Global Institute

The economic growth of IoT-based services is considerable for businesses. Healthcare and manufacturing applications are projected to form the biggest economic impact.

The Internet of Medical Things comprising healthcare applications and related IoT-based services are expected to have an annual economic impact in the range of $2.7trillion to $6.2trillion by 2025.[46] Smart health will see medical wellness, prevention, diagnosis, treatment and monitoring services being delivered efficiently through electronic channels.

The fact that IoT makes use of existing hardware technologies, but requires significant innovation in software and architecture development would create billion-dollar opportunities worldwide for Nigerian entrepreneurs developing and marketing apps.

- Users' livelihoods will be enhanced as farmers, fishermen and others use apps to increase their output and earnings.
- Opportunities abound for general education as people will be able to learn through the Internet.
- Users with disabilities will benefit from using mobile services to communicate, work and shop among other activities.
- Governments – Federal, State and LGA will increasingly use the mobile Internet to communicate with citizens and make information available.
- A variety of mobile healthcare applications will emerge for users to track their fitness or enable remote diagnostics.
- Smart devices will be used to send automatic alerts when the user's security is in danger.
- As with many new electronic devices, the mobile internet will be used for entertainment, including watching videos and playing games.

Emerging technologies such as IoT and AI hold the potential to make the delivery of critical services more efficient and drive advancements in education, healthcare, agriculture and many other aspects of the economy and society.

[46] **McKinsey Global Institute;** https://www.mercatus.org/publications/technology-and-innovation/projecting-growth-and-economic-impact-internet-things

IoT has found acceptance in mini networks such as industrials, household appliances, healthcare especially wearables etc. In the long run, there is going to be a boom in other markets including:

Telecommunications
It is recognised that IoT will bring billions of devices online and network connectivity will be required by these devices to communicate. More device connectivity means more subscription for data services from telecommunication providers.

Manufacturing
The IoT offers great market opportunities for equipment manufacturers, both industrial and domestic. There will be increased demand for smart devices in the areas of security, medicals, education and so forth.

Software
ISPs and application developers are going to experience a boom to their sector as more devices make their entry to the Internet.

Automotive Industry
The automotive Industry will experience a complete reshaping of its business and manufacturing practices as vehicles become smarter.[47]

Security
Monitoring, sensing and tracking will drive up surveillance as the Internet of Eyes gains traction. The aggregate gain would be of a society made safer and more secure by the deterrence of crime engendered by the ubiquity of digital eyes.

Electricity
Smart grid and smart metering will become the norm completely rejigging patterns of energy generation, distribution and consumption.

[47] Disruptive trends that will transform the auto industry; https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/disruptive-trends-that-will-transform-the-auto-industry#

At the Federal and State levels, a number of initiatives have been taken to provide digital services. The Government of Nigeria has recently launched the Central Portal for Government Services.

These applications are increasing as automation enters Government offices. Some of the main back office operations being used include the following.

	Application	Purpose / Benefits	Agency
1	Services.gov.ng	Created to reflect ease of doing business initiatives of Government Ministries, Departments and Agencies (MDAs), in line with the Federal Government executive order. The objectives of the portal include creating a single point of entry to Government information and services, enhancing accountability to improve the delivery and quality of public services through technology-enabled civic engagement, and transforming public administration efficiency;	Federal Government of Nigeria (FGN);
2	Integrated Financial Management Information Systems.	Used for forecasting, debt and procurement management in Government ministries and agencies;	70% of States in Nigeria;
3	Treasury Single Account (TSA)	Deployed to improve cash management in Government offices and reduce the quantum of idle cash in bank accounts;	FGN and 17 States;

4	Integrated Tax Administration System (ITAS)	Intended to automate the Federal Inland Revenue's (FIRS) processes and allow tax returns to be filed online;	FIRS;
5	Integrated Pay and Personnel Management system	With the aim to eliminate ghost workers and improve efficiency in Government payroll administration;	FGN;
6	Geographic Information Service (GIS)	All land titles and property maps scanned and all records digitised. It also modernized approval processes which resulted in the most significant improvement recorded in the Doing Business rankings since 2008;	Many State Governments and the FCT;
7	e-Education	An initiative in various States for upgrading the digital skills of their teachers;	Several States;
8	Digital ID	In 2007, the Government passed the National Identity Management Commission (NIMC) Act and set up NIMC as the Government agency responsible for identification management in Nigeria. To date, NIMC has generated approximately 41.5 million National Identification Numbers (NINs);[48]	NIMC;
9	"Eyes and Ears" Program	This is an App that uses citizen feedback to track the implementation of Government programs and reports to the Governor on the performance of contractors and projects;	Kaduna State;
10	BudgIT	Used to obtain citizens' feedback on Federal and State budgets and other public sector projects across the country;	FGN;

[48] https://technext.ng/2020/06/11/why-over-150-million-nigerians-are-still-without-national-identification-numbers-nin-and-what-nimc-can-do-about-it/

11	The GRID3 project(Geo-Referenced Infrastructure and Demographic Data for Development)	Started in the Northeast of Nigeria as part of the polio campaign funded by the Gates Foundation; has made; Nigeria a leader on the continent in making available high-quality satellite data.[49] A number of State Governments, primarily through their State Bureaus of Statistics, have started using the data for planning purposes. The leaders in this area are Lagos and Kaduna. The potential use cases are numerous, including in the health, education, agriculture, transport, electricity, urban planning and other sectors; and	Borno State Government;
12	Click-On Kaduna	Program in partnership with the World Bank Group and the Rockefeller Foundation. 'Click-On Kaduna' is empowering disadvantaged youth and women between the ages of 18 and 40 in fragile and conflict zones by training them to leverage employment opportunities in the digital economy. The program uses digital technologies to drive innovation, digital skills, job creation and break the cycle of unemployment and violent conflict in Kaduna State.	Kaduna State Government.

Table 6: Government Schemes and Programmes Online

[49] http://grid-nigeria.org

The Government does not have a system for monitoring the use and quality of digital services. A 2018 survey showed that only 2% of citizens use e-Government services.[50] Some of the reasons for this include the following:

- Mobile technology (which is a predominant channel for access in Nigeria) is still short on data services, especially in the rural areas, and so many citizens are caught up in the digital divide
- Awareness of the platforms and range of services is still very low. Large percentages of the population below the poverty line are seemingly oblivious to the potential of the digital economy and participate in it minimally, if at all;
- Most Nigerians do not have confidence in online services, especially in cases of financial transactions because of cyber-security and weak data and privacy protection policies;
- Bandwidth and last mile services to homes have remained a problem for regular and sustained access; and
- Quality of service, which has been a vexed issue, discourages serious online presence and access.

[50] Nigeria Digital Economy Diagnostic Report; World Bank Document

3.10 Objective Seven

What are the current and future uses of IoT across the globe?

Key Findings

The central premise of IoT is to have objects such as appliances, vehicles, machinery and buildings embedded with chips and sensors, allowing them to see, hear, think and perform actions with or without human mediation.[51] IoT generally is an open and comprehensive network of intelligent objects that leverage embedded sensors and actuators to auto organize, share information, data and resources, reacting and acting in the face of circumstances and transformations in the environment.[52]

Although sensors and actuators have been in use for decades, they are now at the forefront of enormous technological change. IoT provides the opportunity to exploit the potential of extremely low-cost sensors and controls with amazing variety, availability, and depth of capability. Vehicles are rolling off the factories with these sensors and controls already embedded. They are already being deployed in environmental monitoring, health monitoring, buildings, security and so forth.

From its initial introduction over two decades ago, the application of IoT has grown to encompass wide and heterogeneous uses - from the very personal or individual uses in physical fitness or medical devices, to planetary scale mechanisms for monitoring climate change and the impact of development. It includes technology for smart homes and smart buildings; smart cities and smart Government; tracking of growth and development; and countries' management of risks, defence and border control.

[51] ISG, Global Internet Report, Internet Society Group
[52] **Jeremy Crumb**, The Policy and Internet Blog, University of Oxford

Any device that is termed smart has been enabled by IoT through its fusion with various other enabling technologies like Internet, Cloud, Edge and AI. The sensors in smart devices, including not just location but also barometers, accelerometers, and others, enable them to be a component of the Internet of Things[53].

The mobile Internet is an early, and critical, part of IoT. Based on the functions built into it, anyone carrying a smart device is potentially part of a worldwide network of sensors that can gather information on their surroundings, and aggregate them into accurate information about location, health, traffic, weather etcetera. The most common IoT devices are smartphones, smart-watches, smart-lamps, voice hubs, smart TVs, home security systems and other smart home automation systems, and home appliances.

IoT takes many forms and is visibly noticeable nowadays in several sectors such as manufacturing, energy, healthcare, transportation, retail, security, and ICT to name iust a few.

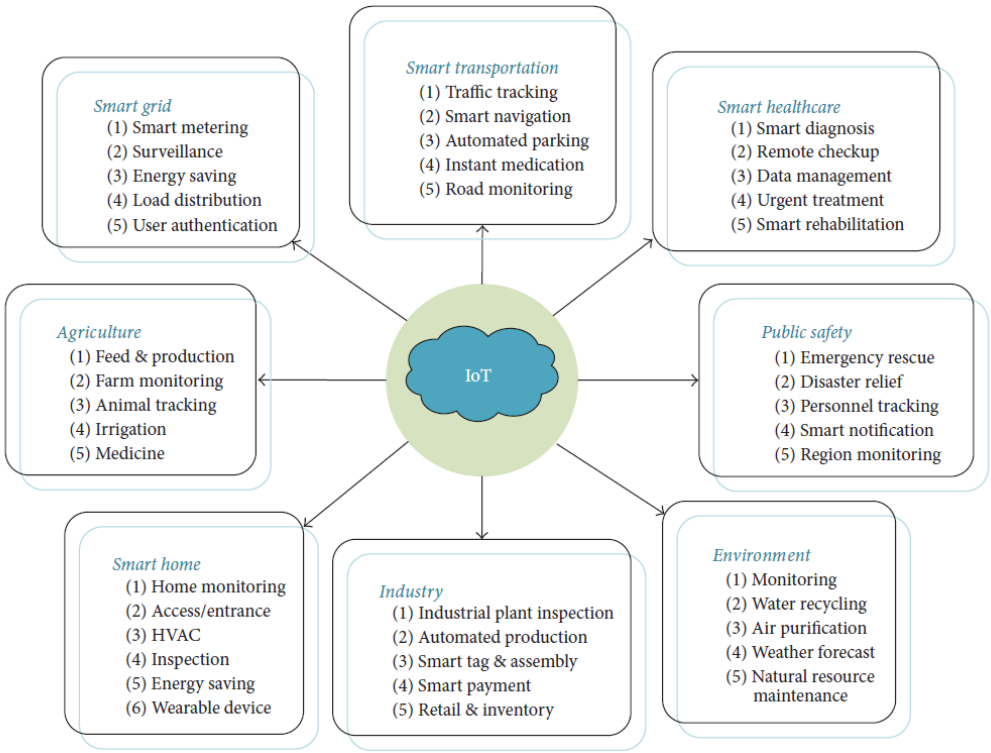


Figure 10: Prospective applications of IoT

[53] **Mohammad Masoud;** Sensors of Smart Devices in the Internet of Everything (IoE) Era:

Globally, it is predicted that by 2025 the healthcare system will dominate the IoT landscape at 41% prevalence closely followed by manufacturing at 33%, energy 7%. Nearly all facets of the economy shall be impacted from healthcare to manufacturing, electricity, urban infrastructure, security, resource extraction, agriculture, retail and vehicles.[54]

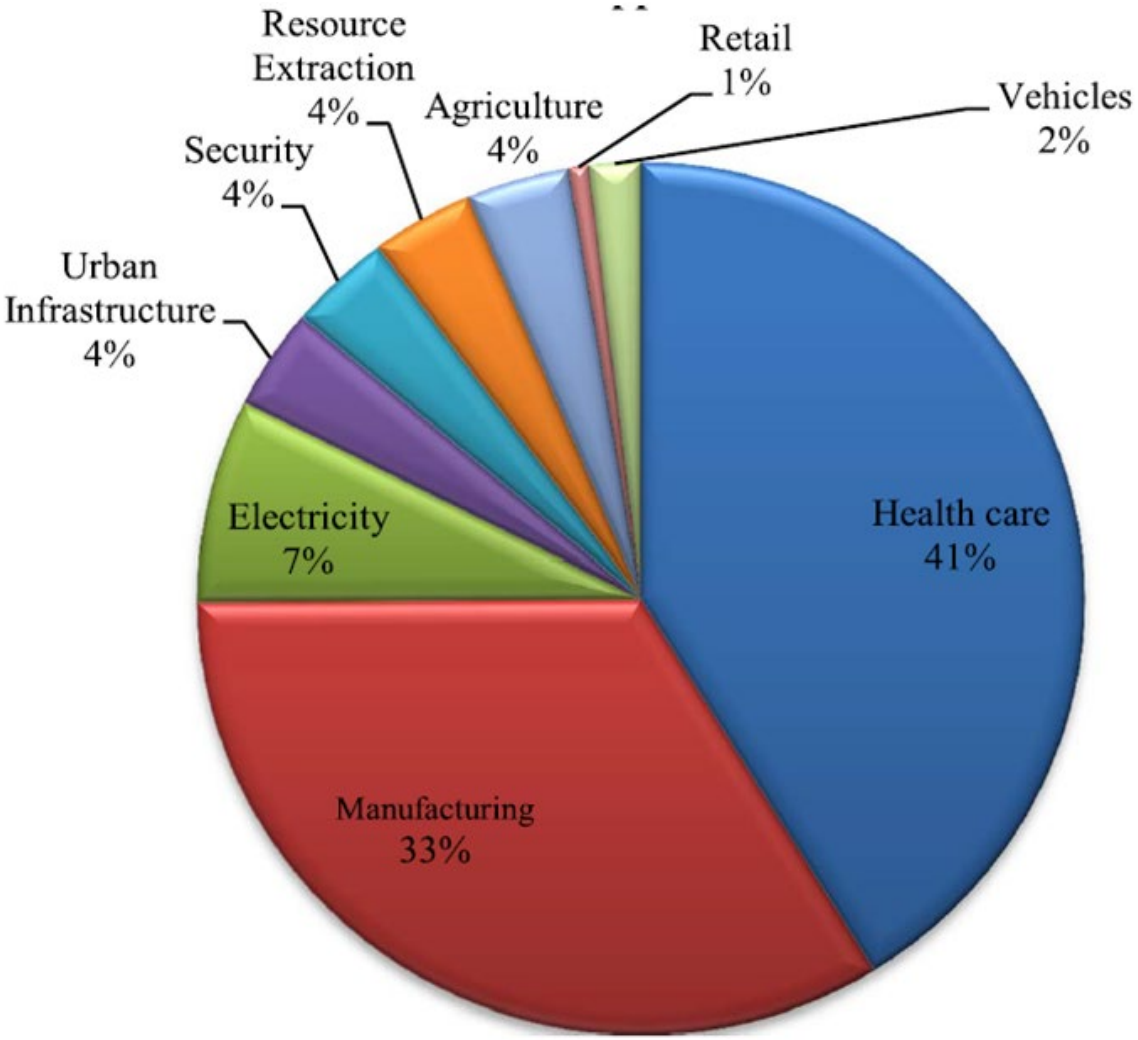


Figure 11: Projected IoT growth by sector

[54] **Analytics, IOT;** The Future of Internet of Things

Some of the most popular use cases uncovered by the study include:

Smart Healthcare

IoT or more specifically Internet of Medical Things (IoMT) with the data it generates opens the door to a world of possibilities for the healthcare Industry. Whether applied to improve lives and control health disorders, or used to track and trace hospital assets; perhaps to administer medication, or facilitate smoother interactions between healthcare providers and customers; or possibly to prevent fraudulent activity, one thing is certain, IoT will benefit the entire healthcare value chain.[55]

From a healthcare monitoring perspective, there are varieties of connected wearable devices, sensors and health applications to track panoply of common health concerns. People now have access to a multitude of health-related data from heart rates and fitness levels, to blood pressure, sleep patterns, insulin levels and even the dispensing of medication.

These devices – both wearable and in the form of smartphone applications – use the Internet to communicate data back to medical aids and healthcare providers. The steady flow of information keeps them apprised of the health state of the wearer, or user, and helps them to avert worsened conditions.

IoT continues to improve the quality of human health by automating some of the basic tasks that humans usually perform. The future portends an explosion in the IoMT for creating a digitized healthcare system, connecting available medical resources and healthcare services. In that sense, most monitoring and decision making will be moved from the human side to the machine side.

One of the main applications of IoT in healthcare is in assisted living scenarios for the elderly or disabled. Sensors can be placed on health monitoring equipment used by patients. IoT devices will be used to monitor patients' current medicines and evaluate the risk of new medications in terms of allergic reactions and adverse interactions. The information collected by these sensors

[55] **MUTISI, TAPIWA MATTHEW;** REVOLUTIONIZING HEALTHCARE SECTOR THROUGH IOT; *innovation-village.com*

is made available via the Internet to doctors, family members and other interested parties to improve treatment and responsiveness.

Hospitals will deploy smart beds that can detect when they are occupied and when a patient is in distress. The smart bed will have the autonomy to adjust itself to ensure appropriate pressure or support is applied to the patient without the manual interaction of nurses. End-to-end health monitoring IoMT platforms will be available for patients, helping them manage health vitals and recurring medication requirements.

IoMT is geared to present patients with the following:

- IoT enabled clinical trial solutions to evaluate specific outcomes;
- Wearable devices to monitor pulse, heart, walking, biking, and other health data;
- Sensor-enabled mobile devices to remotely monitor patients with chronic illnesses; and,
- Wearable sensor patches to give insights on medical effectiveness, health patterns etc.[56]

Cashless transactions

The Nigeria Interbank Settlement Services (NIBSS) observed in one of its reports that PoS, a subset of IoT, is fast becoming the most popular non-cash payment channel, preferred by 93.6% of merchants and 35.8% of consumers. The report stated that electronic payments through PoS terminals rose by 191% to N241 billion in 2014.[57]

[56] **Nidhya R., Karthik S.** *Security and Privacy Issues in Remote Healthcare Systems Using Wireless Body Area Networks*

[57] http://www.vanguardngr.com/2014/12/pos-transactionsrises-191-n241bn-says-nibss/.

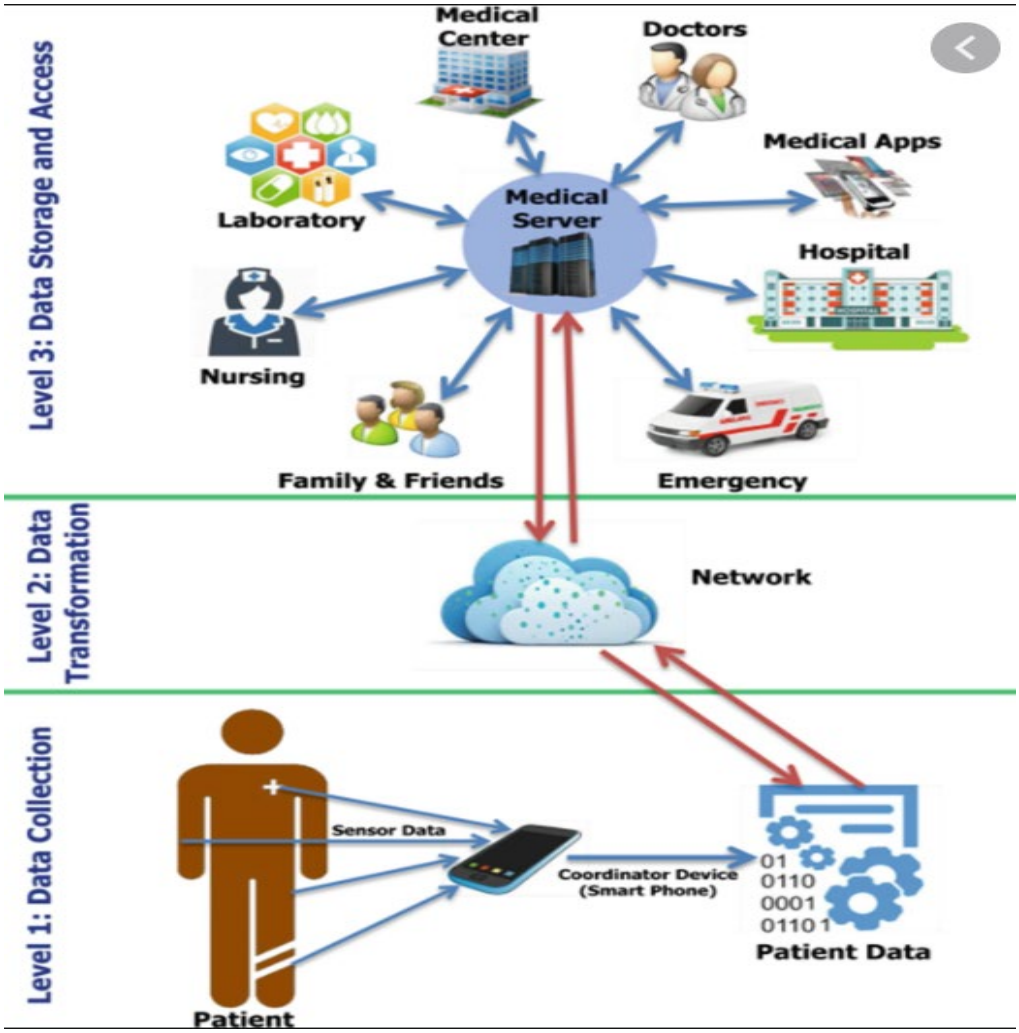


Figure 12: Diagram of IoMT; Source: Nidhya R., Karthik S. (2019)

Manufacturing

Along with improving the effectiveness of manufacturing operations, the Internet of Things or more precisely Industrial IoT (IIoT) as applied in manufacturing ensures proper asset usage, extends equipment service life, improves reliability and provides the best return on assets.

The following are some common uses for IIoT:

- Application of RFID tags with Wi-Fi infrastructure to track real-time productivity;
- Application of smart tools to manage manufacturing processes like measuring, drilling and tightening;
- Remote monitoring of various production equipment to reduce possible downtime, and;

- Predictive maintenance to reduce downtime using sensors installed on machines.

Industrial IoT (IIoT) devices will assume prominence in manufacturing as their use becomes more pronounced driving the seamless integration of various manufacturing devices equipped with sensing, identification, processing, communication, actuation and networking capabilities[58].

By networking machinery, sensors and control systems together, IIoT will enable rapid manufacturing of new products, dynamic response to product demands, real-time optimisation of manufacturing production and supply chain networks.

Figure 13: IoT-based Smart Applications

[58] https://iot-industrial-devices.com/advantages-of-industrial-iot-in-modern-manufacturing-and-smart-environments/

Electricity (Smart Grid)

Electricity grids in many countries are turning smart. Countries such as USA, Germany, UK and China are world leaders in the deployment of smart grids.

The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. It describes an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it including - generators, distributors and consumers - to ensure economically efficient, sustainable power system with low losses and high levels of quality, security of supply and safety.[59]

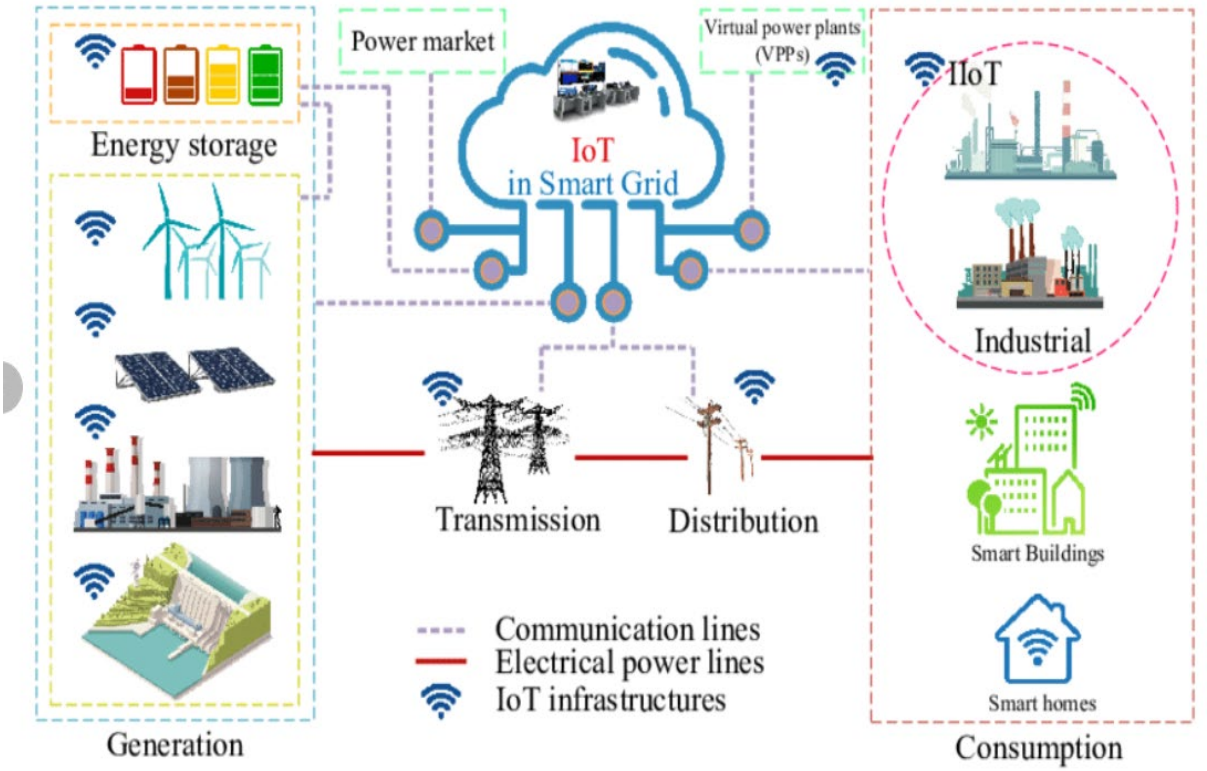


Figure 14: The paradigm of IoT in smart electricity grids**;** Source: www.researchgate.net

[59] The European Union Commission Task Force for Smart Grids; https://en.wikipedia.org/wiki/Smart_grid

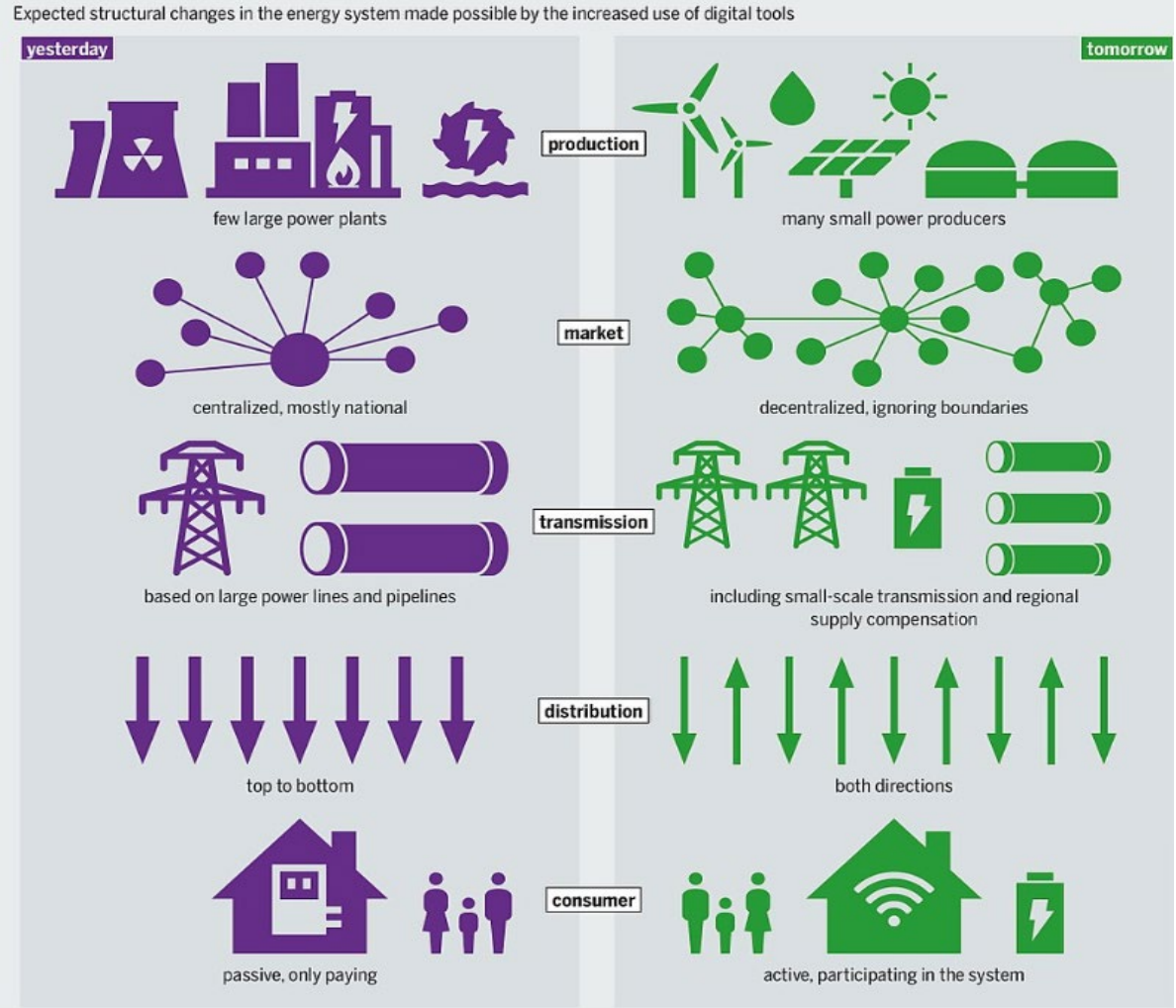


Figure 15: Characteristics of a smart grid (right) versus the traditional system (left); Source: Energy Atlas

A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- Better facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimising the operation of the system;
- Provide consumers with greater information and options for how they use their supply;
- Significantly reduce the environmental impact of the whole electricity supply system;

- Maintain or even improve the existing high levels of system reliability, quality and security of supply; and
- Maintain and improve existing services efficiently.

There will be increased use of IoT technology to collect data about energy consumption and make the data available online. The data may typically incorporate patterns of use and include recommendations for how to reduce energy consumption and cost[60].

Urban Infrastructure (Smart Cities)

More cities are becoming smart across the world. A smart city refers to an urban area that takes advantage of different types of IoT sensors and ICT infrastructures to share information which is employed to manage resources and assets efficiently.[61]

Eko Atlantic City, Lagos promises to be Nigeria's first smart city when it fully comes on stream. In 2019, the top 10 smart cities in the world were London, New York, Amsterdam, Paris, Reykjavik, Tokyo, Singapore, Copenhagen, Berlin, and Vienna in that order.[62]

Smart cities leverage the IoT to enhance the lives of citizens by among other things, improving traffic control, monitoring the availability of parking spaces, evaluating air quality and even providing notification when refuse bins are full.

That means cities being able to automate and collect data through things such as video camera surveillance systems, traffic light sensors, smart devices and so on.

[60] https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT
[61] **Shahinzadeh, Hossein;** ***IoT Architecture for Smart Grids; Sharif University of Technology, Tehran***
[62] **Professors Pascual Berrone and Joan Enric Ricart;** These Are the Smartest Cities in the World for 2019.

Figure 16: The concept of IoT enabled Smart City; Source: Muniba Talha

Smart Homes

IoT technologies are making their presence felt in homes and buildings all over the world. Homeowners and building managers have begun to reap benefits from sensors and actuators that, among other things, track utility consumption, monitor and control building infrastructure such as lights and HVAC systems, and conduct surveillance to meet security needs.

Smart homes consist of hubs, thermostats, lighting systems, fridges, microwaves, coffee makers, in short, every conceivable domestic appliance that will collect data and make machine-learned decisions.

Machine learning is a subset of AI that enables a device to learn what the consumer's preferences are and adjust itself accordingly. The adjustment may then manifest in, for example, an air conditioning unit coming on at a particular time or a TV set switching itself to a particular channel at the occurrence of a pre-defined trigger.

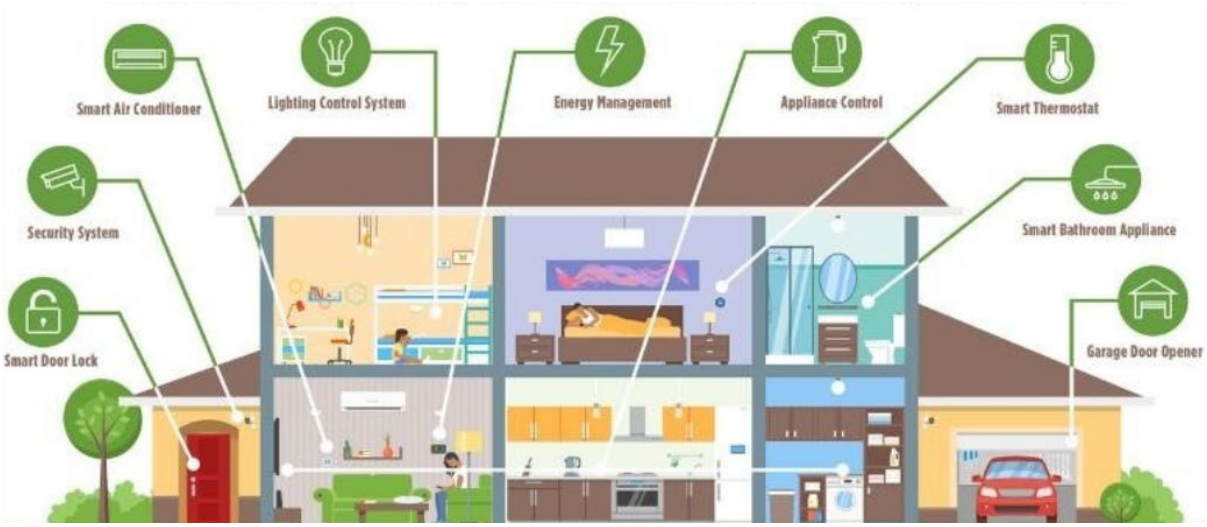


Figure 17: Smart home IoT components and functions;
Source: https://www.bluebonnetelectric.coop

There is a wide variety of IoT uses within the home. From lighting that dynamically adjusts itself according to environmental conditions or a fridge that places an order for supplies when stocks run low or a television that switches itself to a particular channel at the approach of its owner to power controls that auto adjust the timing and use of appliances to align with the owner's preferences.

Security

Closed-circuit television systems have demonstrated that they can do what they are supposed to which is give humans better vision on surveillance. CCTV cameras can only show and record video footage and not much more beyond that as they do not understand what they are watching and cannot do anything about it.

To fight theft, violence, vandalism or fire effectively, cameras must be able to detect and interpret such incidents by themselves. They must also have the capability to cooperate with other systems, such as alarm systems. This is where IoT comes into play. It connects network-enabled cameras with other devices and systems that perform other tasks. Together they turn routine security surveillance into a smart security management system.

Internet of Military Things (IoMT)

The pervasiveness of IoT extends to the armed forces through the Internet of Military Things (IoMT). This is the application of IoT technologies in the military domain for reconnaissance, surveillance, and other combat-related objectives. It is heavily influenced by the prospects of warfare in an urban environment and involves the use of sensors, munitions, vehicles, robots, drones, wearables and other smart technology that are relevant on the battlefield.

A use case IoMT by the Nigeria military is the deployment of Unmanned Aerial Vehicles (UAVs). The Nigerian Air Force (NAF) unveiled Nigeria's first Indigenous UAV to combat insecurity in the country. The UAV is capable of performing both military and civil roles such as surveillance, disaster management, convoy protection and maritime patrol. It is also capable of performing policing operations, pipeline and power line monitoring, border patrol and weather forecasting. The drones enhance the surveillance capability of the army by providing real-time transmission of the battlefield and in helping with the identification of terrorist camps. [63]

Another use of UAVs is in the fight against oil theft and pipeline vandalism. According to a recent Reuters report, Nigeria lost a total of 22million barrels of oil in the first quarter of 2020. The stolen oil amounts to 120,000 barrels per day (BPD) roughly 6% of Nigeria's nearly 2 million BPD output. [64]

The times when video surveillance systems only delivered video that must be continuously observed by humans are over. Machines that are able to record and analyse video data in one go are already available, and they can provide security managers with deep insights instead of single pieces of information.

The IoT-backed security surveillance essentially combines three technologies that will completely change the game: computer vision, automation and deep-

[63] http://www.thisdaylive.com/articles/how-russian-arms-arehelping-nigeria-fight-boko-haram/202513/
[64] https://af.reuters.com/article/idAFKCN1VK1NT-OZATP. *Oil theft cost Nigeria 22 million barrels in first quarter*

learning, driven by powerful processors and apps on cameras. This emerging subset of the IoT is called the Internet of Eyes (IoEyes) - a network of cameras and visual sensors connected via the Internet enabling the collection and exchange of visual data on a scale hitherto unimaginable.[65]

Smart Agriculture

Farming has seen several technological transformations in the last decades and has become more industrialized and technology-driven. By using various smart agriculture gadgets, farmers have gained better control over the process of raising livestock and growing crops, making it more predictable and improving its efficiency. This, along with the growing consumer demand for agricultural produce, has contributed to the increased proliferation of smart farming technologies worldwide.

There will be increased use of IoT applications in agriculture to collect data on temperature, rainfall, humidity, wind speed, pest infestation, and soil content. This data can be used to automate farming techniques, make informed decisions to improve quality and quantity of yields, minimise risk and waste, and reduce the effort required to manage crops.

For example, farmers can now monitor soil temperature and moisture from afar and even apply IoT-acquired data to precision fertilisation programs remotely.

Ordinary Everyday Use of IoT

IoT-enabled devices are nearly everywhere already and in use by many people in their daily activities. Unarguably, any Internet-connected device can be said to possess IoT capabilities albeit to a varying degree. While such devices as smartphones are created to be IoT-ready other devices acquire their IoT capabilities as add-ons or in newer models.

[65] **NISSELSON, EVAN;** It is coming! The Internet of Eyes will allow objects to see.

From the survey results, it can be surmised that nearly all respondents are consumers of IoT already. The numbers range from the 23 persons (0.63%) who have one Internet-enabled kitchen appliance or another to the 2870 people (78%) who use smartphones. It would appear, therefore, that although the concept of the IoT may be new, its utility has permeated people's lives in ways most people are only just beginning to realise.

The core concepts of the IoT are at play from the nondescript gaming console hooked up online to the wrist band monitoring its user's pulse rates or blood pressure and sending the readings through the Internet to a reader elsewhere.

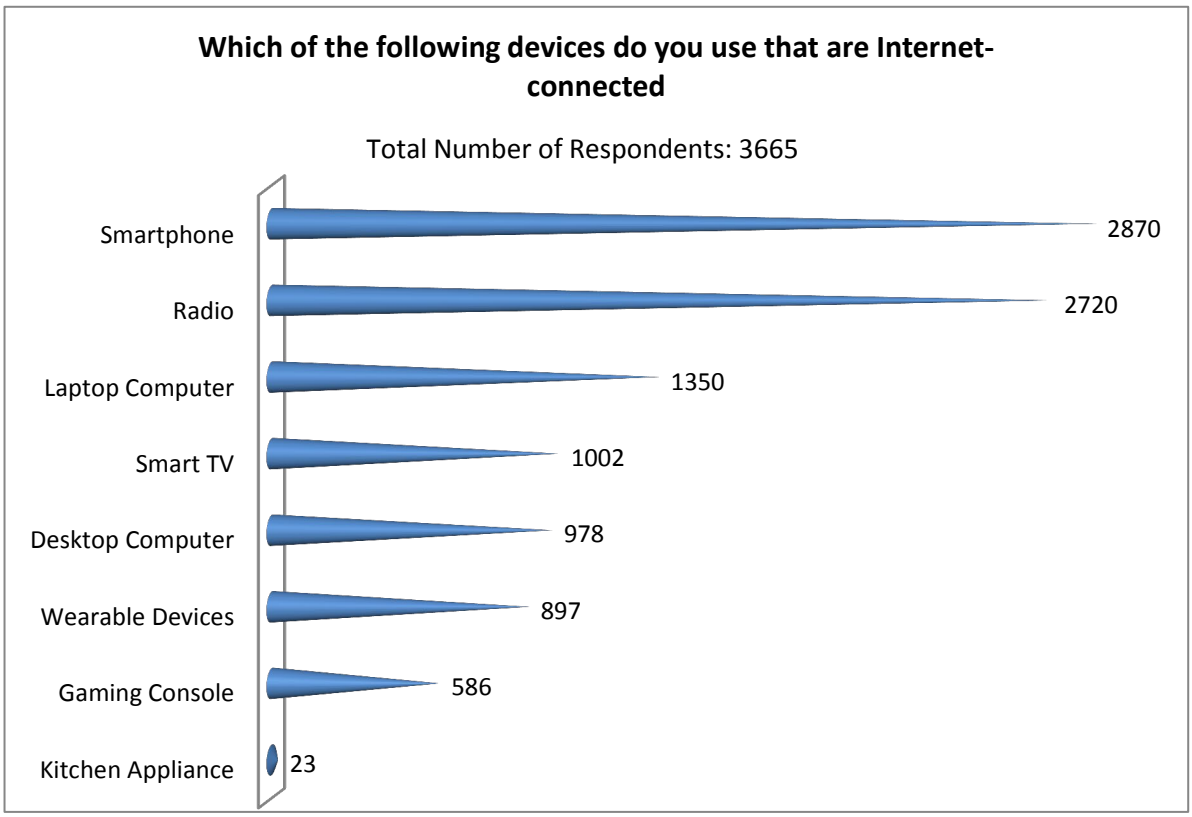


Figure 18: The array of Internet Connected Devices Denoting the Ubiquity of IoT

3.11 Objective Eight

Are there recommendations on suggested amendments to existing licences and/or regulations of the Commission to support the growth and implementation of IoT?

Key Findings

Nigeria has a robust even though complex institutional arrangement to govern and promote advancement of ICT infrastructure and sector development. Overall responsibility for the ICT sector falls under the Federal Ministry of Communication and Digital Economy. The ministry is comprised of three agencies:

- **The Nigerian Communications Commission** - the sector regulator with exclusive powers to license and regulate for commercial providers and users of telecommunications equipment and services;

- **The National Broadcasting Commission (NBC)** – established in 1992, with comprehensive powers over all aspects of private broadcasting in Nigeria, including licensing, monitoring, policy, ethics and standards. However, unlike the NCC, the NBC is subject to ministerial directives and any new license can only be issued upon approval by the President on the Minister of Information's recommendation.

- **The National Information Technology Development Agency (NITDA)** - is responsible for implementing the ICT policy.

The Nigerian Communications Act of 2003 encompasses regulatory intervention in the following areas:

- Tariffs and rates regulation;
- Telecoms licences regulation;
- Licence fees;
- Numbering regulations;
- Spectrum allocation;
- Universal access and service; and
- Infrastructure sharing.

There are two kinds of licences under the Act, namely:

- **Individual licence** granted to a specified person to conduct a specified activity. The terms, conditions, scope and limitations apply to the specific service being provided.
- **Class licence** granted to any or all persons to conduct a specified activity. The terms and conditions/obligations are common to all licence holders.

The telecommunications sector in Nigeria relies on spectrum for the delivery of voice and data services. Mobile is the primary method of delivering communications services in Nigeria and the scarcity of spectrum has impacted on the ability to meet the growing demand for mobile voice and data services and impacted on the quality of service.

The following laws and regulations govern the assignment, allocation and monitoring of spectrum:

- The Nigerian Communications Act of 2003; and
- The National Broadcasting Commission Act 1992 (as amended by Act 55 of 1999).

The main objectives of radio frequency management in Nigeria include:

- Promotion of efficient radio communication systems and services through equitable and fair allocation and assignment of spectrum for the benefit of the maximum number of users;
- Spectrum resource planning, management and monitoring in accordance with international agreements;
- Adoption of advanced spectrum allocation and management techniques for the optimal use of spectrum resources;
- Protection of national interests and the coordination of Nigeria's spectrum policies in bilateral and multi-lateral arrangements; and
- Innovation, research and development in new radio communication techniques, spectrum-based services and applications.

Other objectives of the Spectrum Licence Fees Regulations include:

- A simple, uniform, consistent and efficient spectrum management in Nigeria by standardising frequency spectrum fees and pricing;
- Market value for frequencies proportional to spectrum size being acquired;
- Efficiency and competition in the usage of frequency spectrum; and
- Uniform geographical development of telecommunications infrastructure across.

NCC awards licences and assigns frequencies according to a combination of elements including commercial value, optimal usage, uniform development across geographies and to some extent, universal access and service. This has enabled competitive methods of licensing and frequency assignment, including open or selective auctions either by way of lotteries or 'beauty contests, tenders and fixed price as determined by the Commission.

While on the one hand there seems to be a shortage of frequencies to deliver communications services, on the other hand, frequencies have been either underutilised or even unused as a result of regulatory limitations or possible hoarding by those operators to whom these frequencies have been assigned.

According to Industry experts, the adoption of the IoT in homes, cities and industries is not expected, in the short term, to dramatically increase the demand on current networking infrastructure.[66] Accordingly, the traffic increase due to the IoT adoption would be gradually absorbed by connectivity providers with their network upgrade investment cycles. However, it is necessary to ensure a continuous stream of investment in several areas such as sensor technology development, energy-saving techniques and interoperable software platforms.

When structuring licence policies for the IoT, it is important to note that IoT is neither a single technology nor a new phenomenon. Because of the degree to which IoT technologies represent the natural extension of other existing technologies, any new policy or licensing action will almost undoubtedly have elements of duplication with existing licences.

[66] Global M2M Internet (IP) traffic: From 1% (2014) to only 3% in 2019. http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/VNI_Hyperconnectivity_WP.html

The 2.4 GHz band is probably the most used band for all kinds of applications, including for the IoT. The band supports Wi-Fi, Bluetooth, ZigBee, NFC and many other networking protocols. Originally allocated as spectrum for industrial, scientific and medical applications, today several applications share this band. This is why spectrum managers decided to allow unlicensed use of the band and would, in many cases, like to make more available when appropriate according to market demand.

There is concern about the 2.4GHz-band's utility in the future given its extensive use today, but Wi-Fi in the 5GHz band is less congested and has much more bandwidth, enabling non-overlapping channels and higher throughput. The 5GHz band offers much better performance and less interference, in part because it is less used than 2.4GHz. For IoT manufacturers, the benefit of unlicensed spectrum lies in the low transaction costs of introducing a new innovation. There is no need to negotiate access or face upfront costs from third parties, which makes it effectively a platform for innovation and a fallow space for technology start-ups.

The predicted growth of IoT applications will inevitably increase demand in existing unlicensed bands, especially in the frequency bands dedicated to short range devices (SRD) but not to the extent to raise undue apprehension.

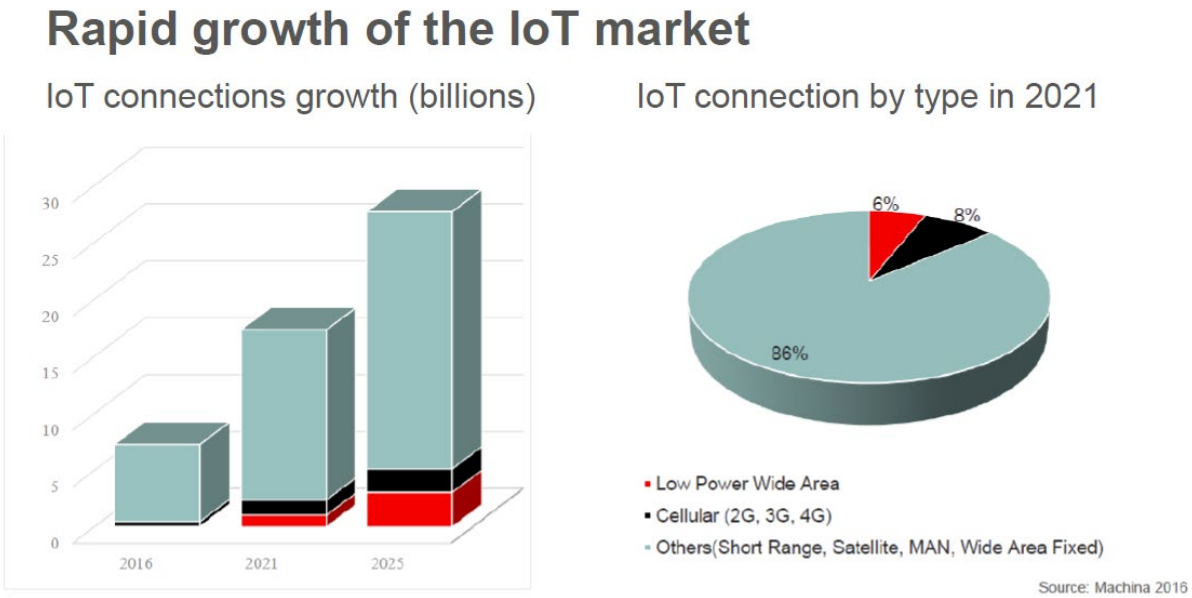


Figure 19: Projected IoT Connections

Unlicensed spectrum levels the playing field. The use of technologies developed in license-exempt spectrum bands, such as Wi-Fi help keep prices low for consumers and gives innovators the extra spectrum space to develop new products.

It is illustrative to examine how other countries are handling IoT licensing:

United Kingdom

The Office of Communications (Ofcom) made available frequency bands on a license-exempt basis for IoT applications in the United Kingdom. After a consultation launched in September 2015 Ofcom concluded that a new license is not necessary to roll-out new services in the 55MHz - 68MHz, 70.5MHz - 71.5MHz and 80MHz - 81.5MHz bands. The regulator affirmed that the current license is appropriate for providing access to the spectrum for IoT and M2M services.[67]

United States

The Federal Communications Commission (FCC) expressed that 5G will likely have to use diverse types of radio access technologies, including macro cells, microcells, device-to-device communications, new component technologies and unlicensed as well as licensed transceivers. It is believed that 5G should accommodate an eventual 1000-fold increase in traffic demand, supporting high-bandwidth content with speeds in excess of 10 gigabits per second (Gb/s); end-to-end transmission delays (latency) of less than one-thousandth of a second; and, in the same networks, sporadic, low-data-rate transmissions among an "Internet of things" – all of this to be accomplished with substantially improved spectral and energy efficiency.[68]

For any finite resource, including spectrum, the primary economic objective is to maximize the net benefits to society that can be generated from that resource. Licences are used as an important mechanism to ensure that the spectrum resources are used efficiently. The broad goals and objectives associated with licensing are:

- Covering the costs of spectrum management activity borne by the spectrum management authority or regulators;

[67] http://stakeholders.ofcom.org.uk/consultations/radio-spectrum-internet-of-things/statement/
[68] http://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db1017/FCC-14-154A1.pdf

- Ensuring the efficient use of the spectrum resource by ensuring sufficient incentives are in place;
- Maximizing the economic benefits to the country obtained from use of the spectrum resource;
- Ensuring that users benefiting from the use of the spectrum resource pay for the cost of using spectrum; and
- Providing revenue to the Government or to the spectrum regulator.

Effective spectrum licensing therefore, is critical to support the investment required to further expand mobile access. It is needed to meet the rapid increase in demand particularly for data services and enhance the quality and range of services offered.

The following key principles will help guide NCC's licensing strategy:

- A presumption of licence renewal encourages long-term network investment;
- High spectrum prices jeopardise the effective delivery of wireless services;
- Predictable and timely spectrum licensing encourages long-term network investment;
- Spectrum licences should be technology and service neutral;
- Licence conditions should be used with caution;
- Licence duration should be at least 20 years to incentivise network investment;
- Competition can be supported by licensing as much spectrum as possible and limiting charges and other barriers to services;
- Voluntary spectrum trading should be encouraged to promote efficient spectrum use;
- Ensure spectrum is available under the right terms for the services which need it most and provide the greatest socioeconomic benefits;
- Encourage spectrum efficiency and innovation so the scarce resource can be maximised; and
- Minimise interference nationally and internationally and support harmonisation.

Services that do not require a license include:

- Sales and Installation of Terminal Equipment (Mobile Cellular Phones, Satellite Communication and Switching Equipment etc.);
- Public Payphone Services;
- Internet Services;
- Prepaid Calling Card Services;
- PNL LEO (Local Exchange Operator);
- Paging Services;
- Trunk and 2-Way Radio Network Services;
- Fixed Telephony Services, Employing Cable and Radio;
- Satellite Network Services (e.g. Domestic VSAT Networks);
- Repairs & Maintenance of Telecommunications Facilities;
- Cabling Services;
- Tele-Centres/Cyber Cafes; and
- Non-commercial/User Operated Radio Networks.

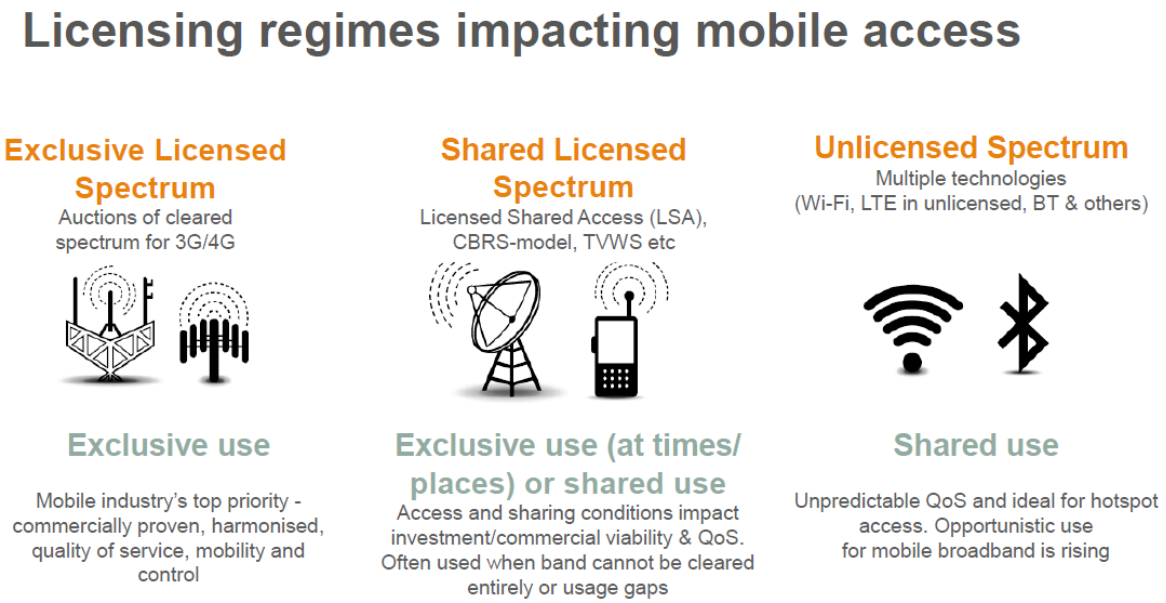


Figure 20: Spectrum Licence Types

Spectrum management appears suboptimal in a number of areas. The regulator needs to review spectrum policy to ensure more optimal coexistence of licensed and unlicensed spectrum. Licensed spectrum is required for the evolution of existing services and needs to be assigned at a competitively determined price to ensure the efficient build-out of capital-intensive networks. Nationally allocated spectrum not in use in remote areas should be

available for free or at low-cost use by community-based or not-for-profit micro-networks.

Innovative use of unlicensed spectrum can also spur investment and innovation in technologies that can complement licensed networks to expand low-cost, last-mile broadband access. Private sector actors are also concerned by an apparent lack of transparency on spectrum allocation that can create uncertainty around long-term investment horizons for the mobile market.

Nigeria's lack of a national backbone network for the transmission of high-speed data is at the heart of prevalent poor quality of voice and data services. While the infrastructure company model sought to address this through the licensing of new players to provide regional backbone infrastructure, the response of Industry has been limited.

In April 2019, NCC announced plans to re-farm existing spectrum (repurpose frequency bands that previously allocated for 2G mobile services, for new generation mobile technology). Having previously sold six slots of 2.6 GHz spectrum band to MTN in 2016, there are currently eight remaining slots of spectrum in the 700 MHz band which can be used to expand 4G LTE coverage and increase broadband penetration across the country. There is scepticism, however, whether more spectrum will have a positive impact on the broadband market, mainly due to established operators in Nigeria having limited resources to both bid for spectrum and roll out the ensuing broadband services, as demonstrated in the 2016 spectrum auction where MTN was the only MNO to bid on the spectrum.

Therefore, to fulfil the National Broadband Policy objectives, NCC needs to develop policies that can lead to a new open access common carrier network with guaranteed national rights-of-way which will attract new investments.

Meanwhile, commercial infrastructure sharing, which is currently being practiced in Nigeria, should be encouraged more in order to reduce the high costs of duplicating networks. However, where this is uncompetitive or the exclusion of other market players, the NCC should investigate the need for

mandatory infrastructure sharing at regulated cost-plus prices. This will lead to the rationalization of unnecessary duplication of infrastructure.

Nigerian fibre operators also spoke about the challenges of obtaining right-of-way and environmental clearances to extend their networks. Various States have different rules, many of them arbitrary and uncertain, and operators have experienced the rules being amended midstream. They have called for national standardized right-of-ways to be made a Federal jurisdictional issue to overcome what is seen as arguably the greatest stumbling block to extension of the national backbone and backhaul networks in Nigeria.

3.12 Objective Nine

What are the ethical issues regarding IoT?

Key Findings

The IoT is not only a technology but a transformational vision of a way of life. Therefore, the role of the Government and policymakers in enabling that transformation is essential especially in the areas of data privacy, security and employment.

The IoT ecosystem will continue to evolve, bringing innovations and also less trust. While democratising access to information, the whirlpool of information and data that exist online raise real concerns around privacy and security.

Impact of IoT on Employment

One key question that arises around the IoT concerns its implications for employment. The IoT raises serious concerns about the inevitability of technology replacing workers in the overall economy. There are economic benefits but also challenges to employment as M2M communication will increase pressures to cut costs and workers may be replaced by machines[69]. There are palpable fears that this scenario is going to become a reality sooner than workers expect.

Ensuring that the IoT can create employment and does not harm the jobs market is a challenge that requires the collaborative effort of Government, Industry and policymakers to be addressed. There are many routine jobs that might decline in the coming years; jobs that now absorb unskilled or low-skilled workers may not exist to the same degree in the future. There will still be jobs associated with providing these functions but many of them will

[69] https://www.internetsociety.org/wp-content/uploads/2017/08/ISOC-IoT-Overview-20151221-en.pdf

require higher skills, such as for repairs and programming of mechanised functions. Having a skilled labour force will therefore be crucial.

While there are different views on the implications of technological change for employment, the IoT promises to increase the discussions of this topic. In many ways, the world is today at the dawn of machine learning similar to where it was at to the introduction of mechanisation at the start of the 20th century, which led to an almost complete replacement of the use of horses for transportation by machines in only two decades.

Technology is moving quickly and the integration of low-cost electronics, large scale processing power and ubiquitous networking will allow (in fact, has allowed) new generations of autonomous and semi-autonomous machines. These machines will move into every part of the economy and may displace workers in various sectors. For example, this could hypothetically lead to workerless factories, airports without check-in and baggage staff, premises without static guards, shops without shop assistants or banks without tellers. Even if it causes only temporary friction in the economy, it is a development that Government and policymakers need to take seriously.

Contrariwise, a recent study with regard to the German market shows that many companies do not expect negative effects of digitalisation on the number of jobs offered by their organisations. In the study 23% of companies even expect new hires to manage the digital transformation.[70] In summary, while the introduction of digital technologies into businesses could bring more jobs in the short term, the long term effects on employment are not yet clear.

Impact on Data Privacy

Regarding privacy, respondents are concerned that if appropriate safeguards to ensure transparency and user control are not put in place IoT could drive data collection and use in ways that further undermine privacy and deepen surveillance. For example, IoT technologies such as facial recognition can improve user experience over a social media platform but the same

[70] See for example a recent study by the Association of German Chambers of Commerce and Industry (Deutscher Industrie- und Handelskammertag, DIHK), "Wirtschaft 4.0: Große Chancen, viel zu tun", cf. https://www.dihk.de/ressourcen/downloads/ihk-unternehmensbarometer-digitalisierung.pdf

technologies can be used to enhance surveillance and compromise anonymity. There may be increased mass surveillance, the further erosion of privacy, and a growing dependence on data collection, analytics, and curation. Without essential precautions, greater amounts of data will be collected and used without the user's knowledge or control. The privacy implications are profound.

Concerns about Security

While lives may be improved by smart homes and smart cities, the IoT's promise of billions of devices constantly transmitting data raises many issues. Some of these issues arise specifically from the ability to access and control various things on the Internet potentially by anyone from anywhere. There are also provenance issues with the devices to consider. The number and relative simplicity of IoT devices greatly expand the attack surface exposed to the Internet.

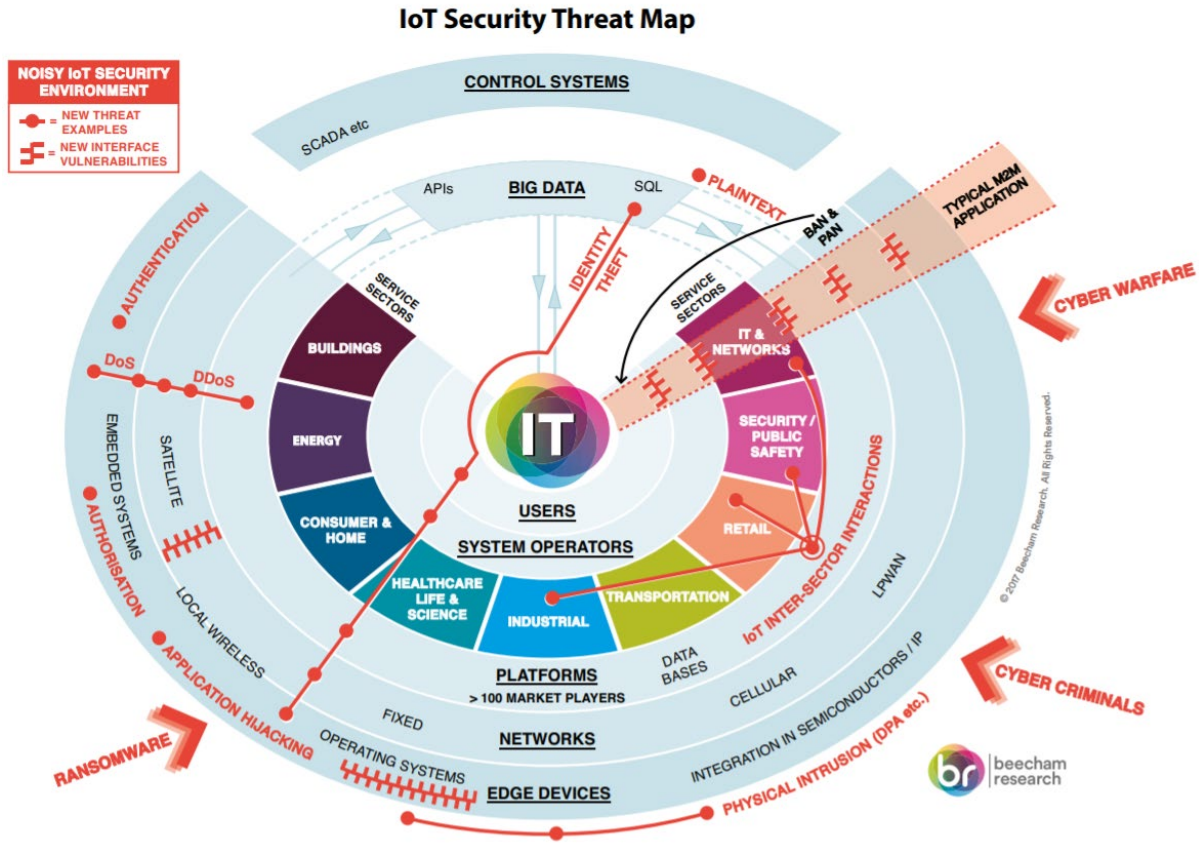


Figure 21: IoT Security threat map; Source: Beecham Research

As indicated, the Internet of Things spans nearly every organization and function. Associated edge devices now expose a series of vulnerabilities that can be exploited by threat vectors.[71] These edge devices can be as simple as a smart light switch or as complex as an industrial control system. They can be fixed in place (security camera), or mobile (smart watch or drone). They can have a focused purpose (thermostat), or be an embedded part of a general-purpose device (a car).

Edge devices can support low-risk tasks like monitoring pollution, or high-risk tasks like controlling the delivery of medication to a patient. Ways in which these devices can be exploited are constantly evolving.

The smart thermostat senses when you are not home and makes that information available to an intruder. A smart TV accepts voice commands and connects to the Internet, but also listens to a room and sends overheard conversations to the cloud. All can be controlled remotely and can send their valuable data through the Internet.

The Vulnerability of manufacturing supply base

With much of Industry using IoT and related industrial control devices, there is a significant potential for such devices to be compromised, and in turn compromise critical manufacturing capability[72].

Subversion of the things themselves

It is not just that IoT devices can be compromised; they may also be counterfeited or subverted during their manufacture. In this way, an attacker does not need to find and exploit the vulnerability as the door was unlocked in advance. The firmware installed on the device may include malware that lets the attacker in or may mount the attack itself. Further, counterfeit versions of chips such as the CPU providing the IoT device's compute power may include backdoors that allow an attacker to defeat encryption and other controls that the real device is designed to use for protection. Uncertainty of provenance, or loss in the chain of custody of critical devices, can allow malicious actors to insert such counterfeit devices into the supply chain. Attackers can reverse-

[71] **Camino Kavanagh**; Stemming the Exploitation of ICT Threats and Vulnerabilities
[72] www.hsdl.org ›

engineer embedded software in a device to create counterfeit products, or locate software vulnerabilities that they then can exploit to steal sensitive data or to tamper with the device for sabotage or other nefarious purpose. An attacker only needs one compromised device among thousands to gain network access.

Ownership

One emerging trend is the shift from device ownership to device licensing. There are several risks associated with this shift. First, users may be dropped from getting needed security patches if their device goes past a certain age. Second, users may not have the ability to properly monitor software components installed on their device due to such restrictions.

The IoT provides many more potential BotNet[73] participants and directions from which attacks can originate. The ability to obtain many dimensions of information about the same assets through various IoT capabilities whose information is aggregated for big data analytics greatly increases the potential benefit of the information. However, it also renders it a far bigger target for attackers looking for high value information.

With much of Industry poised to use IoT and related industrial control devices, the potential for devices to be compromised greatly increases, which in turn can compromise critical manufacturing capability.

While work is being done to build in security to the lower level network protocols the limited compute capability of IoT devices means that they cannot implement the more powerful and sophisticated defence mechanisms that have become widely deployed on traditional servers and end-user computers.[74]

[73] A network of private computers infected with malicious software and controlled as a group without the owner's knowledge

[74] Security Guidance for Early Adopters of the Internet of Things," Cloud Security Alliance Mobile Working Group; April 2015; https://cloudsecurityalliance.org/research/surveys/

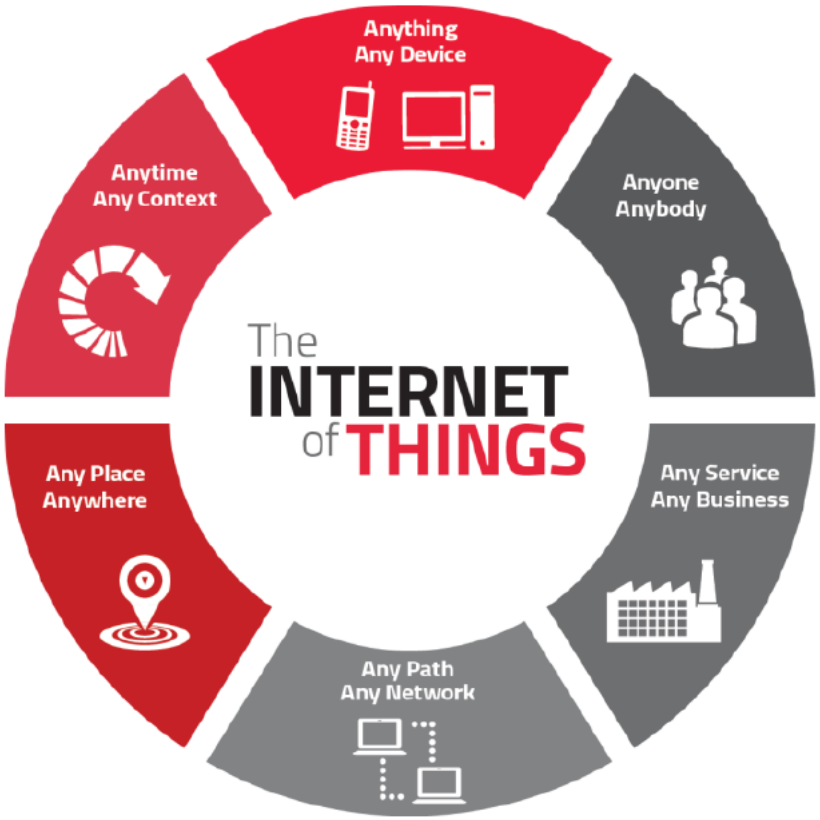


Figure 22: Figure 21: Characteristics of IoT; Source: ResearchGate

In equal measure, the characteristics of the IoT to wit: anything, any device, anyone, anybody, any service, any business, any path, any network, any place, anywhere, anytime and any device are both its strengths and its weaknesses. More of the ethical issues that derive from these characteristics are discussed in the following part.

Ubiquity, omnipresence

The user may become attached to IoT with no clear way out; no way to give up using the objects. The objects will be intelligent and dynamic which make them to be seen as substitutes for social life; they will be extensions not only external of the human mind but of the body too. Being deprived of these devices may lead to problems.[75]

[75] Van den Hoven, J. (2013), *Internet of Things Factsheet Ethics*, http://ec.europa.eu/digital-agenda/en/news/conclusions-internet-things-public-consultation,

Miniaturization, invisibility

The devices will become smaller and transparent thus easily obscure. Making a distinction between objects and beings will be more difficult. There will appear serious problems of identity and system boundaries as a consequence of the easy transformation from one category into another based on tags, advanced design and absorption into new networks of objects. In order to be connected to the IoT, the objects will have an identity. The access to this army of objects and the management of their identities might raise issues and cause problems of security and control in a globalized world.

Ultra-connectivity

The connections will increase in number and reach unprecedented scales of objects and people. Consequently, the quantities of transferred data and products will increase greatly (Big Data) and they could be maliciously used; the interconnected objects might interfere spontaneously in human events in unexpected ways for the users or the designers. The people will be part of the IoT environments together with objects and devices thus creating hybrid systems with unexpected behaviours. The incremental development of IoT will lead to emerging behaviours without the users fully understanding the environment.

Difficult control

The IoT control and governance will not be centralized as a consequence of the great number of hubs, switches and data. The information flows will be eased; the transfers will be quicker and cheaper and not easy to be controlled. There will appear emerging properties and phenomena which will require monitoring and governance in an adequate way and this will further affect the accountability and control activities.

Suggested mitigation steps for the ethical issues highlighted above are encapsulated in the following three challenge areas.

Challenge	Mitigation
Data Privacy	Government and Industry should create an accountability regime, including liability provisions to ensure that those entities that collect, compile and manipulate data are liable for its abuse and its security, not the users. Individuals should continue to have the ability to communicate confidentially, anonymously and securely. Encryption is and should remain an integral part of the design of Internet technologies. Users should be able to control how their data is accessed, collected, used, shared and stored. They should also be able to move their data between services seamlessly. Application and service providers must be transparent about how and why they collect users' data. No one should use personal data to discriminate against individuals or groups of individuals.
Security	Government policy and regulation should specify that manufacturers incorporate security-by-design into devices and systems to prevent the emergence of a security divide. Industry and Government should invest in the creation of usable tools and information to help users make informed decisions about privacy, rights and security. Industry and Government must adopt a risk management approach that goes beyond securing infrastructure and incorporates the principles of responsibility and collaboration. They must develop best practices to protect their networks from internet threats, and protect

	the Internet from vulnerabilities on their network. Security professionals must work collaboratively to test product security and responsibly disclose vulnerabilities. The cost of security failures must be assessed to those who cause the failure, not to the end-user.
Employment	To make the IoT-powered digital economy work for everyone, Government, institutions and Industry must prioritise skills development and training to allow people to keep pace with technology and its impact on jobs. Government and Industry must equip youth and workers with the right skills to connect local talent to the global economy. Government should create an enabling environment for tech entrepreneurship and empower people to create their own globally competitive start-ups.

Table 7: Ethical Challenges Inhibiting IoT Propagation

Finally, regardless of sector or occupation, new work formats will offer individuals and entrepreneurs new opportunities. One example of these new work formats is online platform work, which is on the rise globally. In Nigeria, online talent platforms have the potential to create significant benefits by moving people from informal to formal jobs and by increasing workforce participation and hours worked of those formerly underemployed or inactive. By 2025, this could result in 1.9 million jobs and USD 20 billion additional GDP in Nigeria.[76]

As the nature of work continues to change and for workers to successfully perform digital work, they must develop digital skills. With 46% of work activities in Nigeria susceptible to automation,[77] digital skills will qualify workers for jobs in traditional sectors, while also empowering them to thrive in emerging sectors and even launch their own businesses.

[76] World Economic Forum, 2017
[77] Ibid

Ethical Issues around Data Ownership

There are ethical issues around ownership of the data generated and gathered by IoT implementations. This concern was put out on the questionnaire to Industry Stakeholders to gauge their take. Considering the sensitivity of the issue, 65% of the respondents suggested that the user whose data is gathered should own the data while 30% opined that ownership of the data should reside with the company implementing the IoT system and 5% suggested that an external governing body would be better placed to stake ownership of the data.

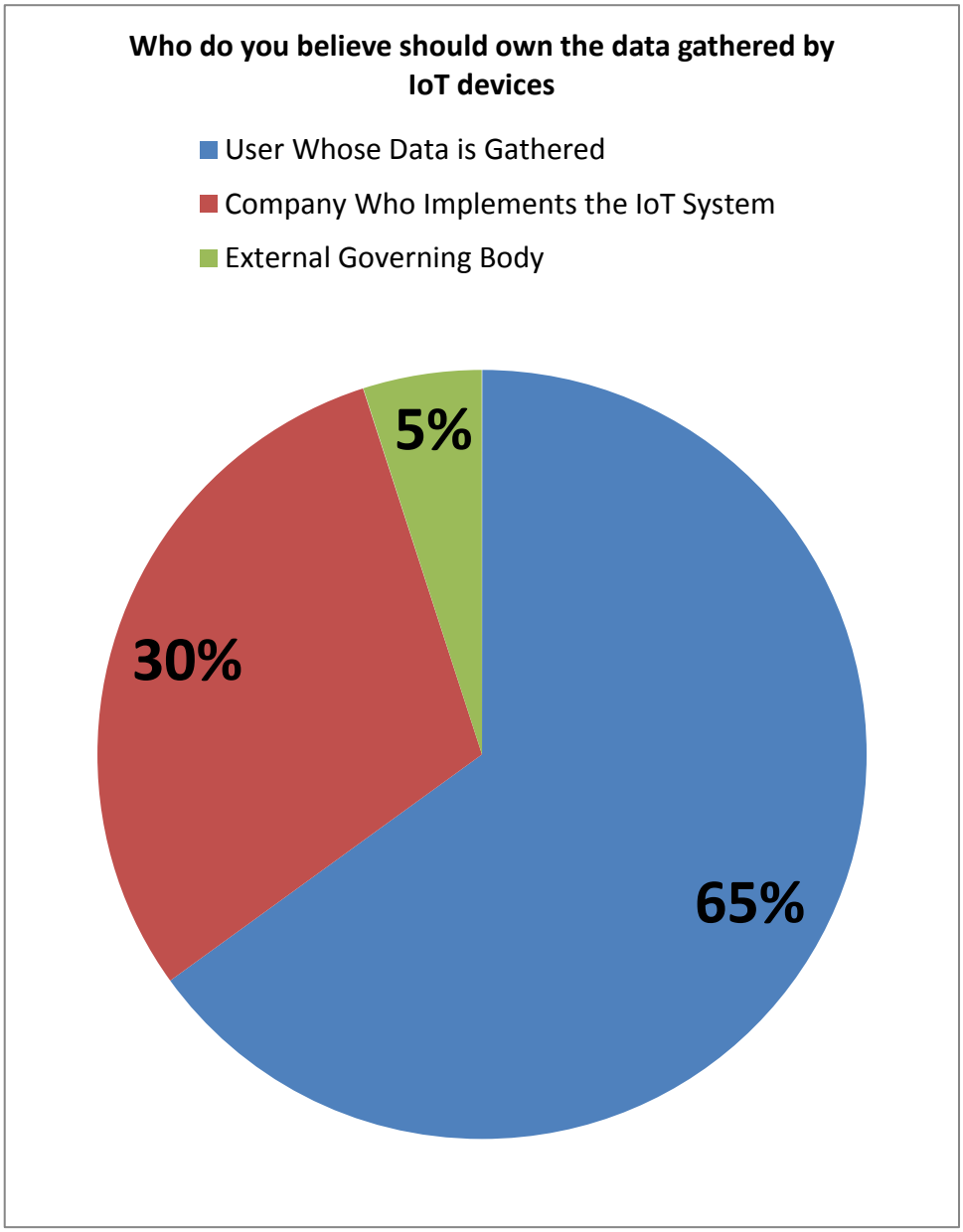


Figure 23: Who Should Own the Data Gathered by IoT

3.13 Objective Ten

What infrastructure needs and gaps exist slowing down the implementation of IoT?

Key Findings

In spite of recent growth in fibre installations in Nigeria, national fixed-line infrastructure is still poor, and mobile systems remain the primary means for carrying retail and enterprise data traffic in Nigeria. Furthermore, fixed broadband penetration in Nigeria is very low, with a household penetration rate of 0.04% at the end of 2018, below the African regional average (0.6%), and well below the world average (13.6%). This is due to backbone investment in Nigeria having focused primarily on major urban areas and inter-city routes, and unlike its West African peers such as Ghana and Senegal, Nigeria does not have a national backbone network through which high-speed Internet connectivity can be extended across the entire country. As a result, mobile broadband has become the most common and popular way through which people in Nigeria access the Internet.[78]

Internet services in Nigeria are currently provided on 2G, 3G, and increasingly 4G mobile networks. However, though 4G coverage is available to 37.8% of the population, download speeds in the country are noted to be generally uncompetitive with other countries in the same income bracket.[79]

At the core of access networks is 2G which covers 87% of the entire Nigerian population. In contrast 3G is presently only available to 54% of the population. The reliance on older access technologies is at the heart of poor mobile data reliability which at the moment is quite pronounced throughout the country.[80]

[78] World Bank Group. 2019. *Nigeria Digital Economy Diagnostic Report.* Washington, DC: World Bank. License: Creative Commons Attribution CC BY 3.0 IGO.

[79] **(FMoCDE), Federal Ministry of Communication and Digital Economy;** *Nigerian National Broadband Plan 2020*

[80] GSMA Intelligence, 2014

For Nigeria to gain the critical number of Internet subscribers needed to build its digital ecosystem and kick-start its digital transformation, innovative solutions and strategic interventions and investments will be required. Nigeria is still a long way from achieving widespread use of broadband because of major infrastructure challenges and market failures, particularly in rural areas. High costs of right-of-way, damage to existing fibre infrastructure as a result of cable theft, road works and other operations, and the lack of reliable grid electricity supply, coupled with low commercial returns, render services not commercially viable on their own. These costs induce a lack of interest from operators and ISPs in deploying infrastructure in rural areas. Accordingly, network operators have focused on the most profitable geographical areas, primarily major urban areas, capital cities and intercity routes, to the disadvantage of the majority who live outside those areas.

As captured in Figure 20 below, broadband connection speed for internet users in Nigeria at 1.56 MB/s is incomparable with say Madagascar, South Africa, Kenya and Morocco where users can expect to enjoy connection speeds that are more than three times faster.

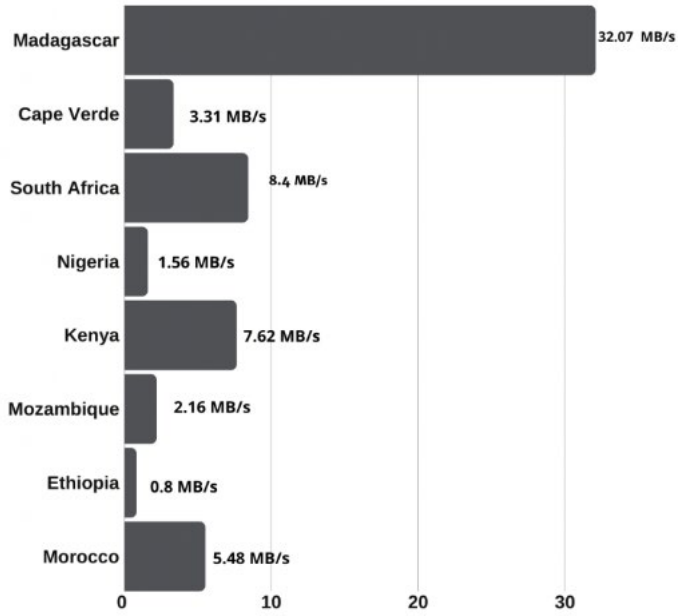


Figure 24: Broadband speed comparison; Source: weetracker.com

In terms of actual connected users, GSMA Intelligence data based on a Q4 2019 survey of a representative sample of the population, suggests that Nigeria's unique mobile Internet penetration (3G and above) stands at 32% or 65 Million individual users against a total mobile Internet subscription base of 125 Million. Mobile broadband connections account for approximately 99.8% of the broadband base while fixed connections are at 0.2%.[81]

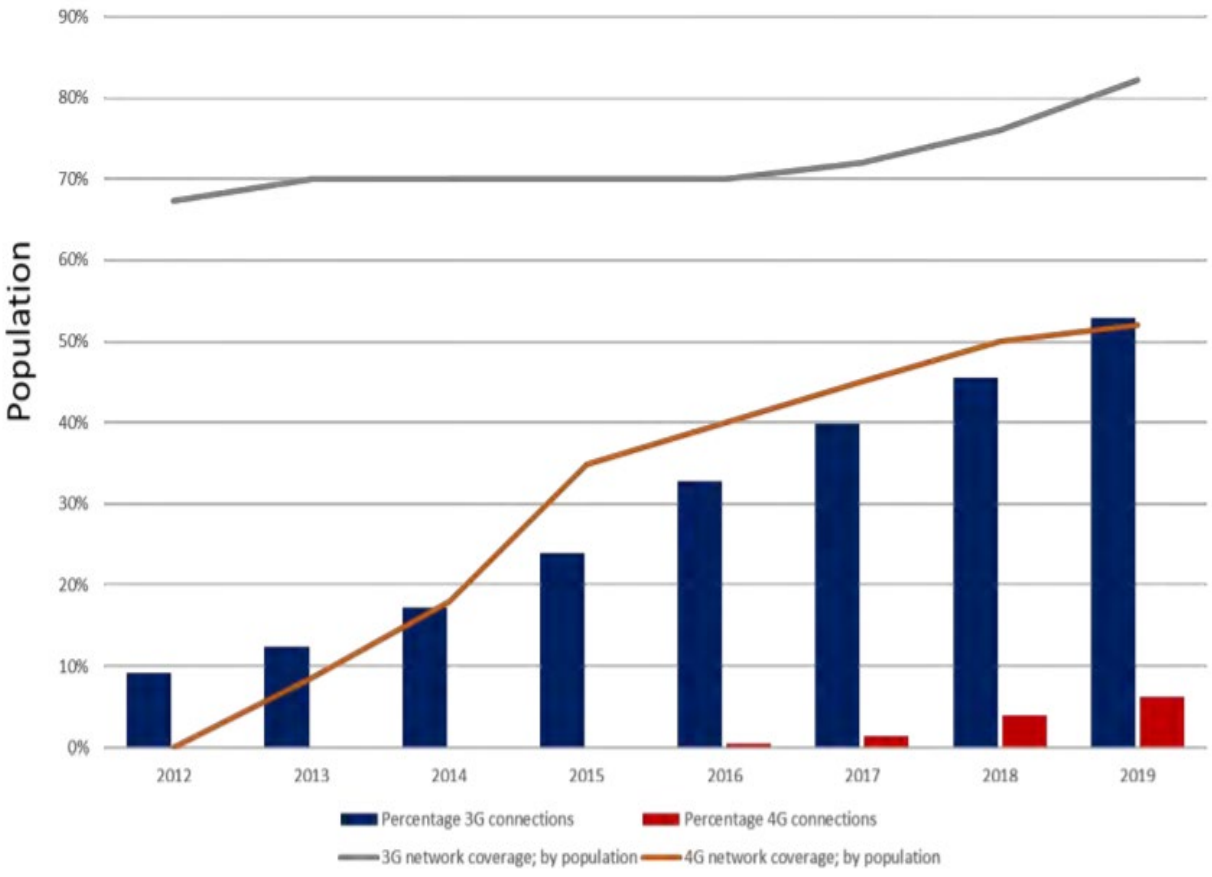


Figure 25: Percentage of 3G and 4G Connections by Population; **Source: GSMA 2019**

[81] NCC - Nigeria National Broadband Plan 2020 - 2025

Access of fibre networks within 5 kilometres of the population currently stands at an average of approximately 39% reach, with a high of 85% in Lagos State and a low of 12% in Jigawa State as shown in the figure below.

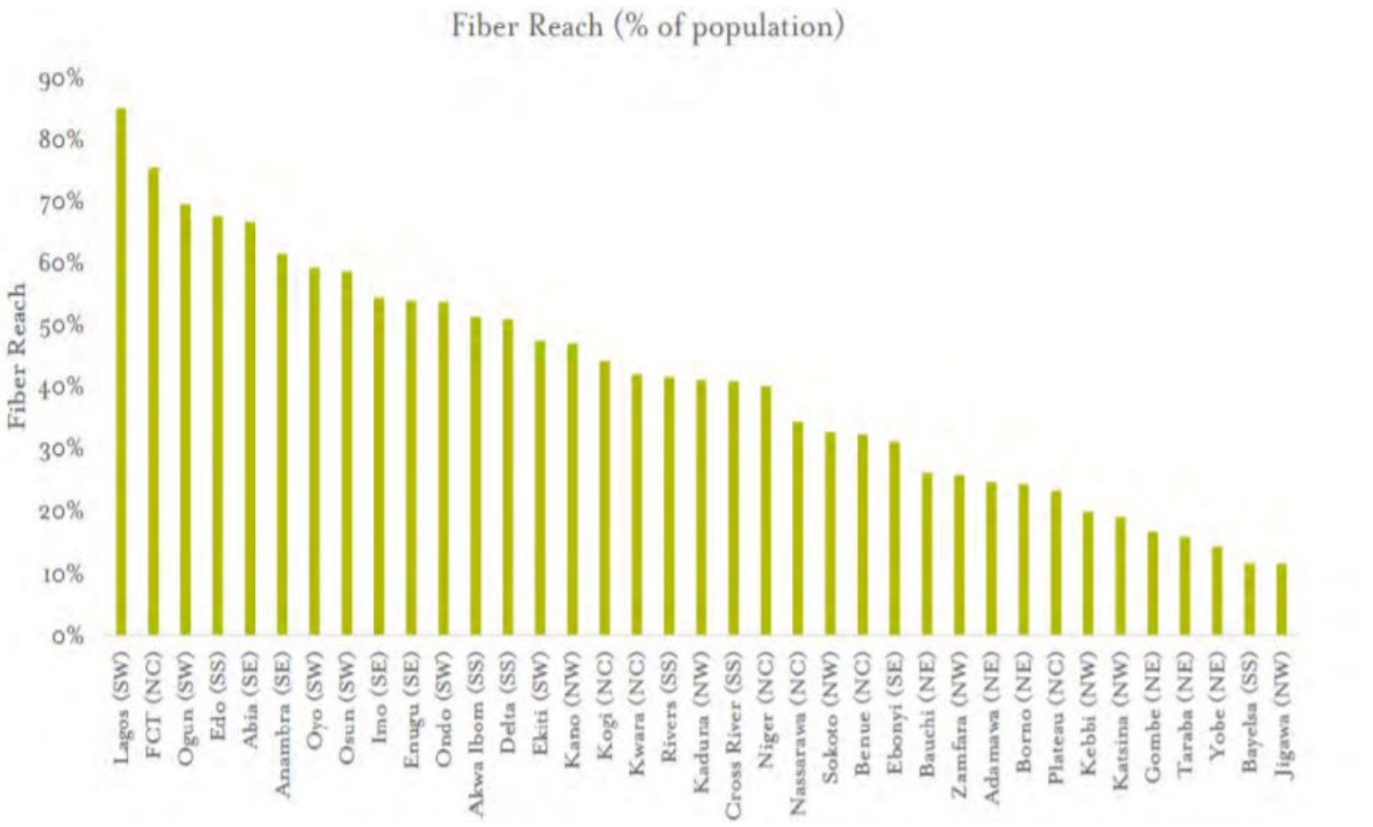


Figure 26: Broadband Penetration by Percentage of Population; **Source: NCC**

IoT is a data-intensive technology and therefore, requires a robust network infrastructure that can handle the large data throughput. It is imperative to have an infrastructure with the capacity to support large data traffic such as 4G and preferably 5G which promises to fuel IoT growth on account of speed and spectrum. Furthermore, devices need to be developed to fit customer requirements in terms of availability anywhere and anytime.

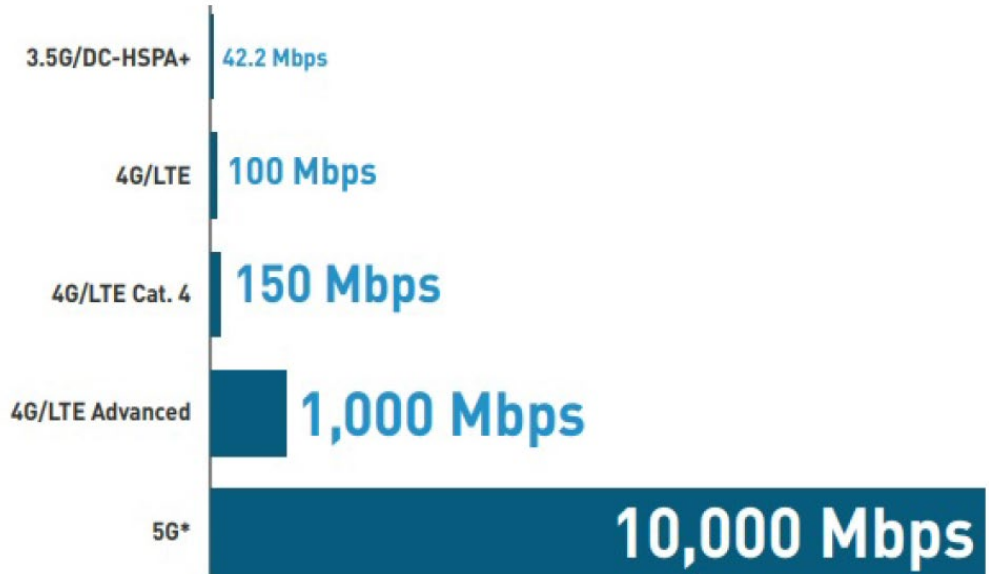


Figure 27: Average 3G, 4G and 5G Connection Speeds

Respondents are in concurrence that to harness the full benefit of IoT, there is a need to increase the deployment of broadband across the country, especially in rural areas. Investing in broadband ubiquity would improve services and help to support connecting the many new IoT devices. IoT will make tremendous demands on the communications infrastructure and data storage, requiring significant investments, by both Government and Industry to shore up capacity.

In some cases, specialised access networks may need to be built to support sensors, for example in smart cities. New protocols may be required for communication compatibility between heterogeneous things - living things, appliances, goods, etc.[82]

There will be increased demand on communication networks particularly with regards to Internet addressing. It is imperative therefore that the Nigeria joins other economies in the march to migrate its IP addressing to IPv6.

[82] Internet of Things for Telecom Engineers A Report on Current State and Future Technologies

The growth of technology firms in Nigeria is plagued by a difficult business environment, lack of early-stage financing, limited market opportunities and a lack of digital skills. These challenges are further compounded by:

- Lack of capacity by Government policy makers to understand new technologies;
- Poor regulatory frameworks and Government-supported monopolies;
- Bias by Governments toward old, existing technologies and hesitancy to adopt new technologies that may dramatically reduce costs or improve impact;
- Data sovereignty and data localization policies that hamper investment in data infrastructure;
- Fragmentation within Government agencies that also hampers the ability for technology to make an appropriate impact;
- Lack of regional integration that hampers ability to get to scale for many business models; and
- Lack of digital skills in the population.

Broadband has the potential to accelerate Nigeria's socioeconomic development. Connectivity can shape the country's development path through several interrelated channels:

- It can bridge the information gap, alleviating asymmetry problems, and improve communication;
- It is the most cost-effective and fastest means of connecting
- all citizens especially those living in the rural areas, to markets and services; and
- It increases productivity, lowers transaction costs, and optimizes supply chains.[83]

Based on affordability and availability, fixed broadband remains a niche service used by public institutions, some businesses and a few privileged households. There are therefore significant digital divides in fixed broadband along affordance and urban-rural lines.

[83] Aker and Blumenstock, 2015

Since 2010, there has been a massive increase in the wholesale submarine bandwidth capacity available to Nigerian telecommunications operators, due to the launch of four new undersea cable systems with landing points into Lagos. This additional capacity has the potential to change the landscape of the Internet service provisioning and data connectivity in Nigeria through lowered wholesale international bandwidth prices and higher speeds.

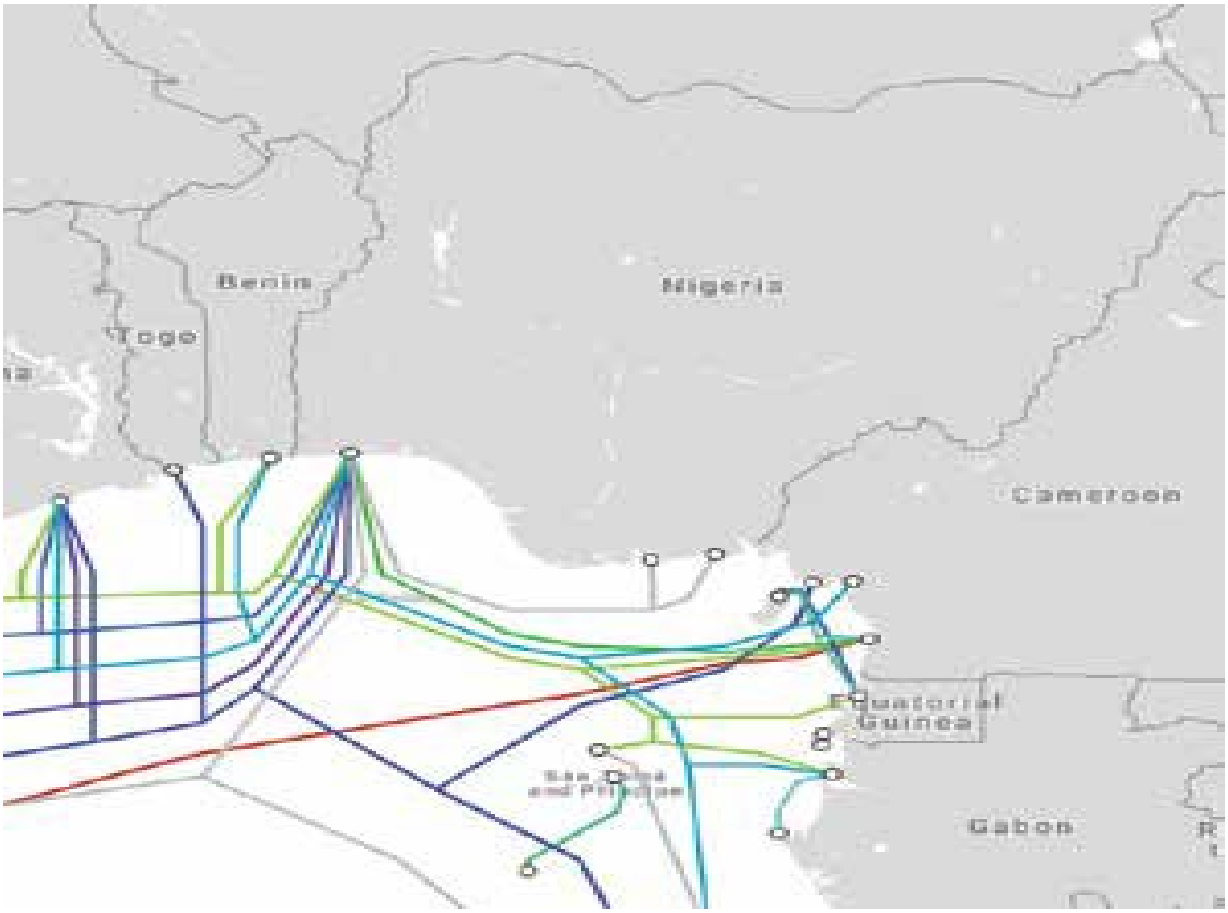


Figure 28: Submarine international links; Source: Submarinecablemap.com

While it is true that submarine cables have expanded the capacity of overall international bandwidth, inland locations within the country are yet to experience any significant lowering of broadband prices. Data rates are still high while browsing speeds are slow and unreliable especially to retail consumers. With very low-income levels among significant segments of the population, it is clear that, even with competitively priced data products, substantial numbers of Nigerians cannot afford the devices to come online or to use the Internet in a meaningful way and enhance their well-being.

Issues with Quality of Service persist in Nigeria. Despite the enormous growth and intensive competition among operators, there is still poor quality of service and network congestion. Lack of coverage and quality of services in terms of network quality and download speed often force subscribers to own multiple SIM cards.

Nigeria's international connectivity is well-developed having been connected to high-speed Internet via the following submarine international cable links system with a combined overall capacity of over 19 terabytes:[84]

- Main One - installed in 2010;
- Glo-1 - installed in 2011;
- West African Cable System (WACS) - installed in 2012; and
- ACE installed in 2014.

The situation was very different pre-2010 when only one international link was available and Nigerian operators were therefore heavily dependent on VSAT systems and nTEL's notorious SAT3 for international bandwidth.

The submarine cables provide adequate redundancy for possible fibre/cable cuts, and total available international bandwidth has been increasing rapidly, reaching a potential capacity of 19.2 terabytes. While Nigeria benefits from the landing and interconnection of many submarine cables, with estimates of over USD 1 billion (NGN306 billion) worth of investments, outside of Lagos this sizable international connectivity has had little impact on the domestic market. The Industry consensus is that the cost of moving traffic inland from any of the submarine cable landing points in Lagos to any location within the country is now higher than the cost of purchasing bandwidth from anywhere outside the country.

Backbone investment in Nigeria has focused primarily on major urban areas and on inter-city routes. Unlike its West African peers, such as Ghana and Senegal, Nigeria does not have a national backbone network through which high-speed Internet connectivity can be extended across the entire country. Currently, all the operators together contribute about 52,000 km of fibre optic cable, 33,000 2G, 29,000 3G and 4,000 4G/LTE towers,[85] significantly fewer than far smaller countries and economies.

[84] https://www.submarinecablemap.com
[85] https://m.guardian.ng/new/telecoms-operators-deploy-52000km-fibre-optic-cable-to-bridge-access-gap/

The biggest infrastructure companies with significant network assets in Nigeria are, in ascending order:

- nTEL (formerly NITEL)
- Phase 3
- 9Mobile
- Airtel
- IHS
- Glo
- MTN

There is an imbalance among the major three telephony operators -MTN, Glo-Mobile, and Airtel - in the endowment of national connectivity infrastructure. MTN has a much wider fibre-optic network than any other operator. Access to MTN's network is not sufficiently regulated to ensure open and non-discriminatory access. This lack of open access is a serious drawback to stimulating competitive broadband development and the sustainability of the business model of the ISPs that have recently entered the market.

Despite recent growth in fibre optic cable installations, national fixed-line infrastructure is still poor and mobile systems remain the primary means for carrying retail and enterprise data traffic in Nigeria. Fixed broadband, which generates very high construction costs, is in short supply, even within towns excepting perhaps Lagos and Abuja.

Notwithstanding the influx of fibre-optic operators into the country, which correlates with the potential of the country's communications market, last-mile infrastructure deployment to end users remains minimal. Therefore, the Internet sector still depends on wireless access technologies.

The minimal last-mile infrastructure deployment and the resultant slow connectivity constitute major concern for stakeholders and impede the propagation of IoT in Nigeria.

Respondents were categorical that second only to interoperability, connectivity poses a major concern for them in their IoT deployment strategy.

Stakeholders rated Connectivity at 35% second to Interoperability 37% as a key concern regarding IoT. Security was also rated as a major concern by 18% of the respondents. Only 10% of respondents regarded the IoT Ecosystem in general is a key concern.

Some of the implications of these findings are that most organisations would be better disposed to roll out IoT deployment in their establishments once quality of connectivity improves and with assured interoperability between diverse devices and applications.

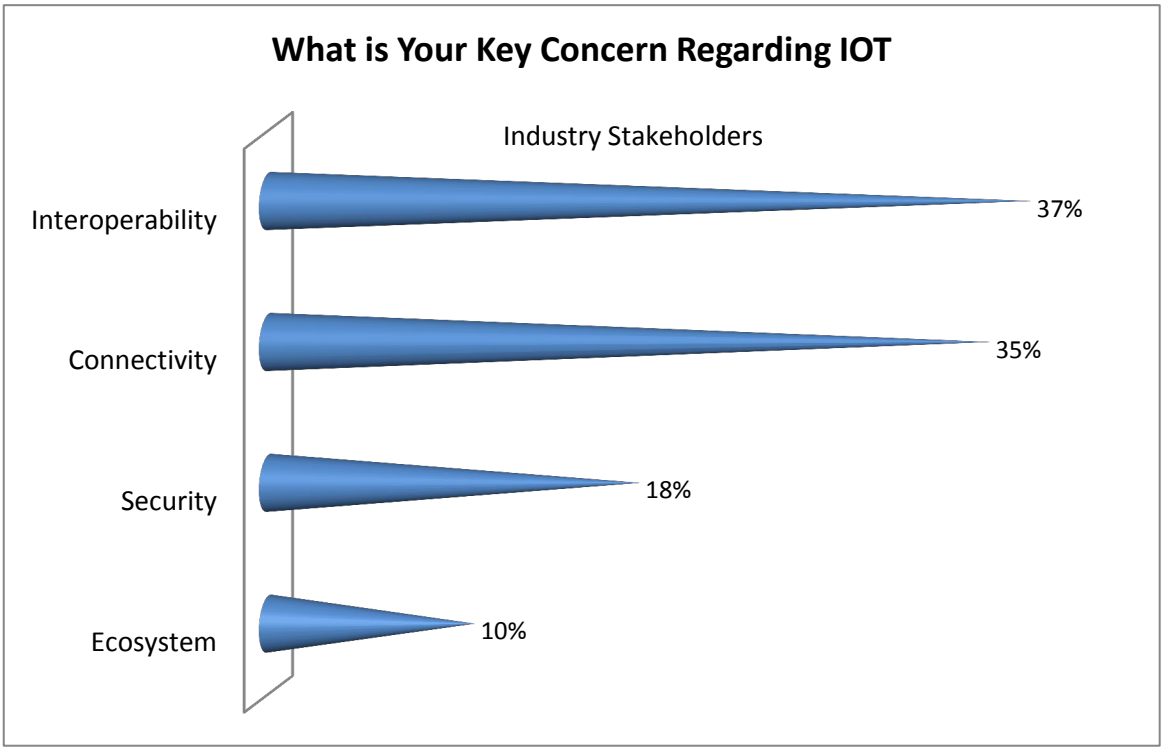


Figure 29: What is Your Key Concern Regarding IoT

3.14 Objective Eleven

What are the Nigeria customer needs and expectations from IoT?

Key Findings

The Covid19 pandemic thrust the many advantages of IoT in bold relief. Smart devices have become commonplace in performing tasks that hitherto required laborious efforts or physical presence. At the entrance to most public places, smart devices are deployed to instantly read visitors' temperature and pulse rates to ascertain that they will pose no considerable health hazard when admitted into the facility.

Classroom lessons, business meetings, home shopping, banking and virtually all human endeavours have become accomplishable online. Virtual classrooms, virtual worship places, virtual markets, virtual meeting rooms have now become the trend. The ability of IoT to introduce these new efficiencies in all aspects of life is driving a broad set of new expectations including:

Better access to public services

Respondents registered their expectation that the use of technology to conduct Government business would engender better access to public services and reduce bureaucratic red-tape. Such improved access is noticeable with electricity smart metering. No longer do Energy Company operatives have to call at addresses to read meters nor do consumers have to visit any office to purchase electricity. Both tasks can now be accomplished digitally.

Improved safety and security for citizens

Respondents expressed their anticipation that public safety and security would improve tremendously as many ordinary devices acquire monitoring capability. As IoEyes matures and gains traction almost everything and everywhere will

have virtual eyes[86] monitoring all activities thereby improving public safety and security.

Improved and affordable healthcare

Expectations are rife that healthcare in general, particularly its procurement and delivery would witness radical improvements. It is envisaged that most situations that would normally require a patient presenting physically before a medical practitioner will be resolved remotely. The use of wearables to monitor human health and environmental conditions would become the norm[87]. IoT wearables would continue to enable people to better understand their health and allow physicians to remotely monitor patients. This technology will also enable companies to track the health and safety of their employees which is especially useful for workers employed in hazardous conditions. Internet of Medical Things is expected to gain firmer traction and completely assert itself in this regard.

Respondents registered various other expectations including that IoT would:

- Create new efficiencies in manufacturing through machine learning and product-quality monitoring;
- Improve the tracking and ring-fencing of physical assets;
- Drive efficiencies and new possibilities in existing processes. One example of this is the use of IoT to increase efficiency and safety in fleet management;
- Enable changes in business processes for example, the use of IoT devices to monitor the health of remote machines and trigger service calls for preventive maintenance;[88]
- Drive innovations in clean water, disaster preparedness, relief and disease prevention;
- Increase productivity and efficiency of business operations;
- Create new business models and revenue streams; and,

[86] **It's coming! The Internet of Eyes will allow objects to see**; https://thenextweb.com/insider/2016/05/13/the-internet-of-eyes-and-the-personification-of-everything-around-you/

[87] **The Rise of Consumer Health Wearables**; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4737495/

[88] **Why is IoT so important**?; https://www.oracle.com/ng/internet-of-things/what-is-iot.html

- Easily and seamlessly connect the physical business world to the digital world to drive value.

People come first

The final theme running through the respondents' responses is the imperative of putting the human users first. This underpins the expectation that the Internet must continue to benefit people and create new social and economic possibilities, thereby fulfilling the premise on which it was built[89].

The survey results show that 29% of respondents who welcome more IoT capabilities around waste management, 15% said they would like to see more domestic appliances acquire IoT abilities while 30% would like to see more IoT in parking.

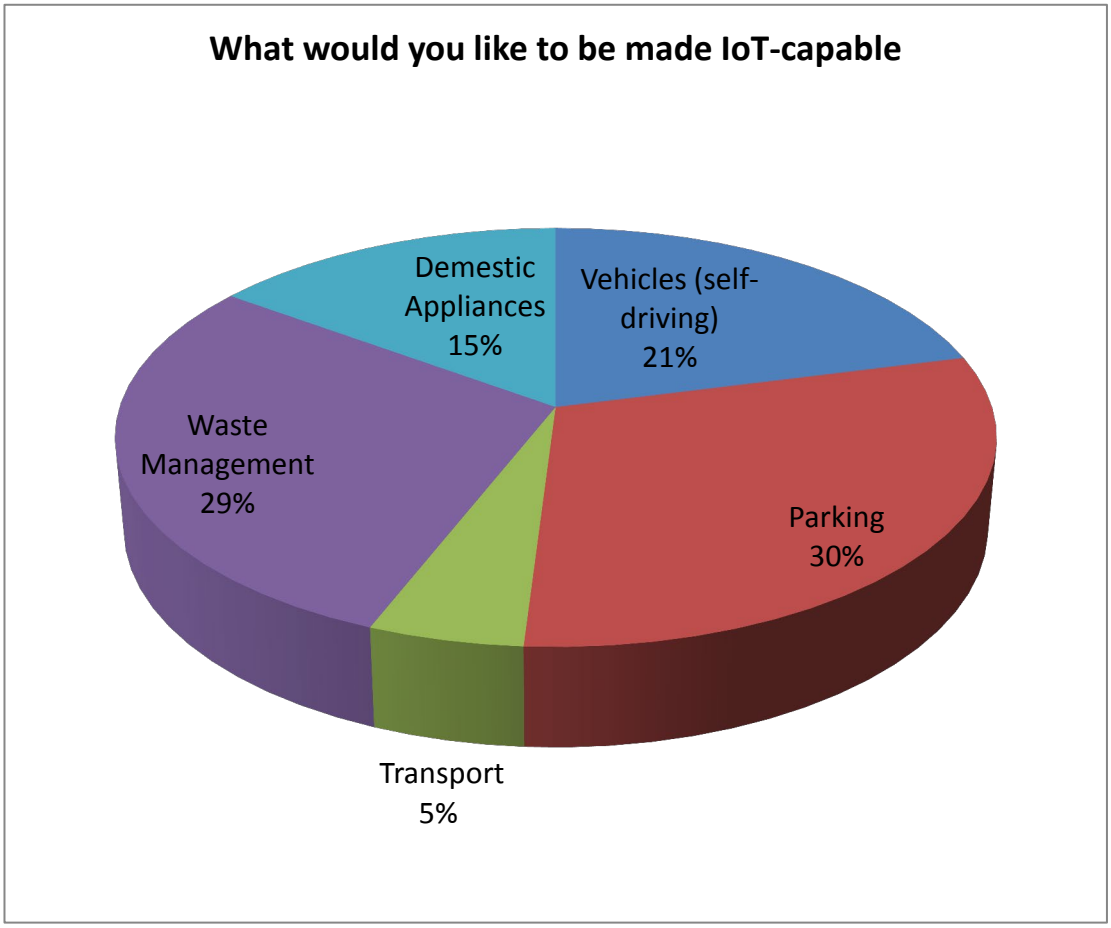


Figure 30: What would you like to be made IoT-capable

[89] https://future.internetsociety.org/2017/conclusion/

3.15 Objective Twelve

What and where are the competitive market forces requiring IoT?

Key Findings

In 2015, the Nigeria Communications Commission's 8-Point Agenda proposed the transitioning of Nigeria's economy into a digital economy through investment in digital infrastructure, more specifically broadband, which represents a key growth driver of the IoT. The agenda's goals are to facilitate broadband penetration, improve quality of service, optimize usage and benefits of spectrum, and promote information communication technologies innovation and investment opportunities across the country.

To deliver on these aspirations the Government needs to create an enabling regulatory environment for the digital economy to grow; pursue radical reforms that bring about improved skills and a more competitive digital job market; support public-private partnerships to stimulate and sustain demand for the use of digital platforms; and improve the current business climate to boost more investment opportunities.

Almost all organizations are best suited for IoT. However, it is expected that IoT will first find its acceptances in the following sectors which are those that will benefit from using sensor devices in their business processes.

Manufacturing

Manufacturers will gain competitive advantage by using production-line monitoring to enable proactive maintenance on equipment when sensors detect an impending failure. Sensors can measure when production output is compromised. With the help of sensor alerts, manufacturers can quickly check equipment for accuracy or remove it from production until it is repaired. This

allows companies to reduce operating costs, get better uptime, and improve asset performance management.

There will be increased automation introduced into most manufacturing processes which will boost productivity and tremendously reduce costs.

Automotive

The automotive Industry stands to realize significant advantages from the use of IoT applications[90]. In addition to the benefits of applying IoT to production lines, sensors can detect impending equipment failure in vehicles already on the road and can alert the driver with details and recommendations. Thanks to aggregated information gathered by IoT-based applications, automotive manufacturers and suppliers can learn more about how to keep cars running and car owners informed.

Transportation and Logistics

Transportation and logistics systems benefit from a variety of IoT applications[91]. Fleet of cars, trucks, ships, and trains that carry inventory can be rerouted based on weather conditions, vehicle availability, or driver availability, thanks to IoT sensor data. The inventory itself could also be equipped with sensors for track-and-trace and temperature-control monitoring. Companies involved in temperature-sensitive logistics would benefit greatly from IoT monitoring applications that send alerts when temperatures rise or fall to a level that threatens the product.

Retail

IoT applications allow retail companies to manage inventory, improve customer experience, optimize the supply chain and reduce operational costs[92]. For example, smart shelves fitted with weight sensors can collect RFID-based information and send the data to the IoT platform to automatically

[90] https://www.oracle.com/ng/internet-of-things/what-is-iot.html
[91] **Ed Kuzemchak**; The benefits of IoT in transportation: An industry case study
[92] https://www.iotforall.com/retail-iot-applications-challenges-solutions

monitor inventory and trigger alerts if items are running low. Beacons can push targeted offers and promotions to customers to provide an engaging customer-service experience.[93]

Public Sector

The benefits of IoT in the public sector and other service-related environments are similarly wide-ranging. For example, Government-owned utilities can use IoT-based applications to manage metering, billing and supplying of their products and services. They can also use IoT to notify their users of mass outages and even of smaller interruptions of service. IoT applications can collect data concerning the scope of an outage and deploy resources to help utilities recover from outages with greater speed.

Healthcare

IoT assisted monitoring provides multiple benefits to the healthcare Industry.

General Safety across All Industries

In addition to tracking physical assets, IoT can be used to improve worker safety. Employees in hazardous environments such as mines, oil and gas fields, chemical and power plants need to know about the occurrence of a hazardous event that might affect them. When they are connected to IoT sensor-based applications, they can be notified of accidents or rescued from them as swiftly as possible.

[93] **Retail IoT: Applications, Challenges, and Solutions**

3.16 Objective Thirteen

Is there a need and market for IoT in Nigeria?

Key Findings

Nigeria is Africa's largest market for digital products and services, but its growth is constrained. Despite its protracted economic recession, Nigeria remains Africa's largest ICT market with 82% of the continent's telecoms subscribers and 29% of Internet usage.[94] However, overall digital literacy rates remain low, especially among women, and low-income and rural populations. Micro-entrepreneurs and local SMEs are also missing out on digital dividends.

Nigeria's e-commerce market is the largest in Africa, but the sector struggled in recent years. The e-commerce market in Nigeria is estimated at $13 billion[95] with big home-grown players like Jumia and Konga. For further growth, e-commerce firms will need to overcome severe challenges, most importantly the lack of infrastructure across the country that hinders logistics and the lack of trust by Nigerians in e-commerce that will require significant efforts at consumer awareness building.

According to the Nigerian Content Development and Monitoring Board (NCDMB), the Nigerian software market is estimated at $12 billion annually[96] due to broadband expansion. It is currently dominated by products from Asia and Europe with some imports from the United States, but the market segment for high-quality products remains largely unsaturated.

Nigerian software producers are mostly small and young companies that lack products and expertise to capture market opportunities. However, fintech companies are increasingly gaining ground. There are examples across all firm growth stages: start-ups Paga, Flutterwave, and Paystack along with older firms like Interswitch and SystemSpecs. Some Nigerian software developers have expanded outside the country. For example, Flutterwave has offices in Kenya, Ghana, and Uganda.

[94] **A. Gillwald Et Al**; The State of ICT in Nigeria 2018
[95] Jumia, 2019
[96] https://www.nigerianbulletin.com/threads/nigerias-software-market-worth-12bn.108950/

The largest current demand is from large organisations based in Nigeria, but they source globally. In Nigeria, financial institutions and telecoms have a high rate of technology utilization, growing needs for digital products and services, and have the capacity to pay. However, there is significant competitive pressure and high entry costs for digital entrepreneurs to acquire and scale up a corporate customer base in Nigeria, especially for younger start-ups.

Digitization of services offers the opportunity for expanding the local business-to-business (B2B) and business- to-customer (B2C) markets. Increased penetration of digital payments can expand the opportunity for digital solutions for local SMEs, including traditional industries and individual customers. Digital technology can also facilitate low-income farmers' integration into value chains for high-quality products for advanced country markets.

Another growth opportunity is created by the expansion of e-Government. The Nigerian Government is increasingly using the Internet to provide better information and services to its citizens. For example, there have been extensive efforts to automate business registration, and most of it can now be done online.

Digitalization of public services is also creating new opportunities for entrepreneurs. For example, the e-voucher system has been introduced in Nigeria for distributing subsidies for seeds, fertilizer, and other farm inputs and may eliminate intermediaries, reduce corruption and leakages, and enhance efficiency. This may open the market for digital platforms and other ventures that integrate digital technology in their service and delivery systems. The increasing pressure on public authorities to extend the reach of basic services to the marginal communities and regions, and to be more responsive, accountable, and transparent, creates more demand for public agencies to hire digitally skilled employees and partner with digitally enabled businesses for delivering services.

However, e-services are inaccessible for many communities that have limited access to the Internet. The Government has several initiatives and programmes aimed at digitalising the delivery of public services and for bringing as many citizens online as possible. These initiatives include the following.

Table 8: Government Programmes to Encourage Digitalization of the Economy

	Initiative	Purpose	Agency
1	The 2012 National Information and Communication Technology (ICT) Policy	Lays out the sector direction with the main goal of creating a favourable environment for the rapid expansion of ICT networks and providing services that are accessible to all at reasonable costs and that contribute to the development of the various socioeconomic sectors. Key objectives include; ▪ to facilitate and support development of a nationwide ICT infrastructure that will support national broadband connectivity and accelerate socioeconomic development; ▪ to connect all Federal and State networks to a national fibre backbone; and ▪ to provide a reliable, accessible, secure and reasonably priced ICT connectivity to national and international ICT infrastructure.	Ministry of Communications Technology, 2012.
2	The National Broadband Policy (2013–2018)	Recognizes the positive linkages between increased broadband penetration and GDP growth. The plan envisages more than a fivefold increase in Internet and broadband penetration, for metro fibre	Ministry of Communications and Digital Economy

		infrastructure to be installed in all state capitals and urban cities, while other estates and business districts within major cities would have fibre to the home or premises. At a national level, the intention of Government is to facilitate full rollout of wireless 3G networks by operators and transition to 4G/LTE as spectrum becomes available.	
3	Community Resource Centres (CRC),	Aims to extend voice and ICT training and other e-services to underserved communities on a shared basis and bridge the digital divide in the communities. The centres are fully equipped with desktop computers, furniture, telephones, power generators and bandwidth to provide access to telephone, Internet, ICT, and e-initiatives at peri-urban, rural unserved and underserved areas.	Universal Service Provision Fund (USPF)
4	The Rural Broadband Initiative (RUBI)	Provides subsidies to operators for the deployment of a network to support the establishment of core delivery mechanisms for broadband services in the rural/semi-urban areas of Nigeria. Currently, the pilot wireless mobile broadband hot spots are being constructed across the country. This project provides both wired and wireless Internet at high speeds in the rural areas at	USPF

		wholesale, and at the same time serves as a catalyst for the uptake of other broadband-dependent projects in those locations, such as e-library, e-health, and e-Government.	
5	School Knowledge Centres (SKC)	Provides public secondary schools with connectivity, computers and power backup. Teachers and students are taught how to use ICT as well as one-year technical support. The USPF is also supporting the development and deployment of local content under this program.	USPF
6	e-Accessibility Project:	Provides ICT tools and Assistive Technologies (ATs) to the blind, deaf, dumb, crippled, cognitively impaired, and other categories of people living with disabilities. The project is designed to assist in improving the quality of life of people living with disabilities by: ▪ Providing support to identified groups in accessing information and communication technologies; ▪ Improving the overall learning experience of persons living with disabilities by equipping educators with the right hardware and software; and ▪ Providing ICT and assistive solutions to cover as many	USPF

		areas of disability as possible, including but not limited to sight, hearing, mobility etc.	
7	The Smart Nigeria Digital Economy Project	Expands broadband coverage, increasing e-Government and establishing ICT clusters, starting in the Special Economic Zones (SEZs). Government will also drive a program to build the skills in this sector, focusing on training ICT engineers in software development, programming, network development and cybersecurity. The Project's objective is to increase the contribution of ICT and ICT-enabled activities to GDP by an estimated 10% and create 2.5 million new jobs between 2017 and 2020.	Nigerian Office for Trade Negotiations (NOTN)
8	Vision 2020	Recognizes the importance of ICT skills development and greater diffusion of ICT across subsectors within the economy, including education, finance, farming, trade, manufacturing, services, oil and gas and the public sector. The strategic initiatives envisioned to drive implementation of policy within the ICT sector include: ▪ Providing the appropriate incentives to drive the development of ICT	Federal Government of Nigeria

infrastructure and telecommunications services to rural and underserved urban areas;

- Mainstreaming ICT into the education curriculum;
- Encouraging local production of ICT components and subsystems by providing incentives for manufacturers for major ICT projects;
- Facilitating the development of a national multimedia superhighway;
- Establishing a national (spatial) ICT backbone
- Connectivity and Bandwidth Aggregation Solution;
- Implementing the Nigerian National ICT for Development (ICT4D) strategic action plan to foster a competitive environment with ample opportunities and choices;
- Establishing a national digital library with access points strategically located in both rural and urban areas;
- Promoting e-learning, e-governance, e-business, e-commerce, e-banking, e-management, etc.;
- Providing regular and affordable access to the

	Internet resources in all educational and research institutions, with particular focus on basic and post-basic education; ▪ Establishing appropriate legal and regulatory frameworks to support e-business and ICT; ▪ Providing appropriate incentives, including tax benefits and improve infrastructure, with a view to creating an enabling environment that encourages investment, innovation, and exploitation of ICT-enabled services; and ▪ Mainstreaming ICT policies into the broader development of a knowledge society and ensuring coordination and consistency between ICT policy strategies and national development policies.

Although motivations vary from organisation to organisation, what is constant is that many organisations and businesses are beginning to appreciate the crucial role IoT will play in injecting efficiencies into the execution of their operation processes and the delivery of their products and services.

Ranging from being innovators to being followers of market trends, organisations retain different reasons and purposes for deployment of the Internet of Things.

Majority of the survey respondents (40%) posited that their IoT deployment is because there is a need in the market for it while 20% said the motivation is to simplify and improve people's lives.

Those who said that IoT Strategy is their business focus came to 12% of the total number of respondents. On the other hand 10% of organisations are happy to let market trends drive their IoT deployment.

What is immediately discernible from the findings is that many organisations are keying into the need to infuse IoT into their corporate strategies and operations which portends great opportunities for sector stakeholders.

Figure 31: The Main Reasons Driving IoT Deployment by Organisations

3.17 Objective Fourteen

What are the best models, products and segments of IoT that will likely thrive in Nigeria?

Key Findings

A business model describes the rationale of how an organization creates, delivers, and captures value.[97]

An IoT business model is one that:

1. Focuses on capturing and delivering value.
2. Leverages the unique characteristic of 24/7 connectivity of IoT products to produce innovative and differentiated value.

The distinct IoT Business Models that hold the potential to thrive in Nigeria include the following:

- Subscription
- Outcome-Based
- Asset-Sharing
- Razor-Blade
- Monetised IoT Data
- Per-Per-Usage
- Offer-A-Service

The characteristics of these business models and their intrinsic benefits are fully described in Table 8.

[97] **Sterwalder, Alexander.** *"Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers"*

Table 9: Distinct IoT Business Models

Model	Characteristics	Benefits
Subscription	Leverages 24/7 connectivity to develop a recurring-revenue model i.e. Software as a Service, monitoring as a service and predictive maintenance as a service.	Fosters an active company and customer relationship.
Outcome-Based	Here customers pay for the outcome (or benefit) the product provides, as opposed to the product itself.	Can reduce the customer's objection to buying expensive equipment.
Asset-Sharing	Such as car-sharing, bike-sharing, virtual power plants, shared drones, etc. Why pay for the full price of a car if it's going to be parked idle 90% of the time.	Cost and risk-sharing.
Razor Blade	IoT product can be designed for selling other products.	Lucrative for products that have consumables needing constant replacement i.e. printers.
Monetised IoT Data	Think of energy efficiency devices installed in buildings to monitor their energy consumption. The building manager benefits from this data, but utilities or other aggregators can pay a	

	hefty sum to receive the aggregated data.
Pay-Per-Usage	Using the data produced by the IoT device to track usage e.g. pay-per-mile insurance.
Offer a Service	Use an IoT product to monitor machinery, predict maintenance, and then sell a maintenance contract.

Business Segmentation

The complexity of the IoT is going to create new opportunities in traditional business services including the following:

Business Consulting

The endless connected devices, staying connected securely, and making sense of the mountains of big data that will be generated will create a huge opportunity for specialist consultants to the business units making decisions.

Compliance

Compliance is another big opportunity in IoT, which includes building out policies, conducting risk assessments, and ensuring the physical network is safe. The edge becomes much more vulnerable when there are 50 billion or more devices that cybercriminals can hack into, which provides opportunity for cybersecurity providers that understand how to protect the edge.

Procuring, Provisioning, Deploying

There will be opportunities in sourcing devices and software from the thousands of competing vendors, provisioning them with the right network and security protocols, and staging them for deployment. The margins here will be great, especially in the first five to 10 years that might rival the first 10 years of the PC market.

Software Integration and Protection

The opportunities for highly skilled industry specialists who can piece together complete software stacks to do major corporate roll-outs will abound. The average IoT deployment requires several pieces of software and hardware, all of which must be secure, compliant and integrated requiring integrators who know their onions.

Custom Software Development

Organisations uninterested in extending their application programming interfaces (API) or dedicating engineering talent for one-off solutions will be happy to hand such projects over to partners; this will result to a lot of developers, programmers being hired. There will be tons of API work necessary to pull off IoT rollouts which will create immense opportunities for software engineers at all cadres.

Majority of Industry Stakeholders believe that the theatre of activity for the IoT development in Nigeria would occur in Healthcare and Wearable Technologies followed by Industrial Automation & Control Systems.

The Industrial Automation & Control Systems encompass remote monitoring of sites, automation of manufacturing processes, sensing and actuating in agriculture and Industrial IoT in general.

Home Automation is another segment of IoT that respondents believe would witness lots of activities by device and software manufacturers alike and an area that would generate diverse businesses for stakeholders.

Healthcare and Wearable Technologies came in as the sector with the highest vote from respondents at 41%. This is perhaps because wearable devices are already enjoying tremendous ubiquity evidenced by the preponderance of health monitoring devices and gadgets that people wear these days. These gadgets range from blood pressure monitoring wrist straps, smart watches that measure pulse rates and body temperature as well as the proliferation of IoT-enabled healthcare gear in medical facilities.

Respondents rated Industrial Automation & Control at 19% making it second in the top two IoT market verticals for Nigeria. Home Automation came in at 13% and Energy Management 11%. Respondents also believe that Smart City implementations would account for 8% of IoT activities in Nigeria in the coming years. Artificial Intelligence and Transportation brought up the rear at 5% and 3% respectively.

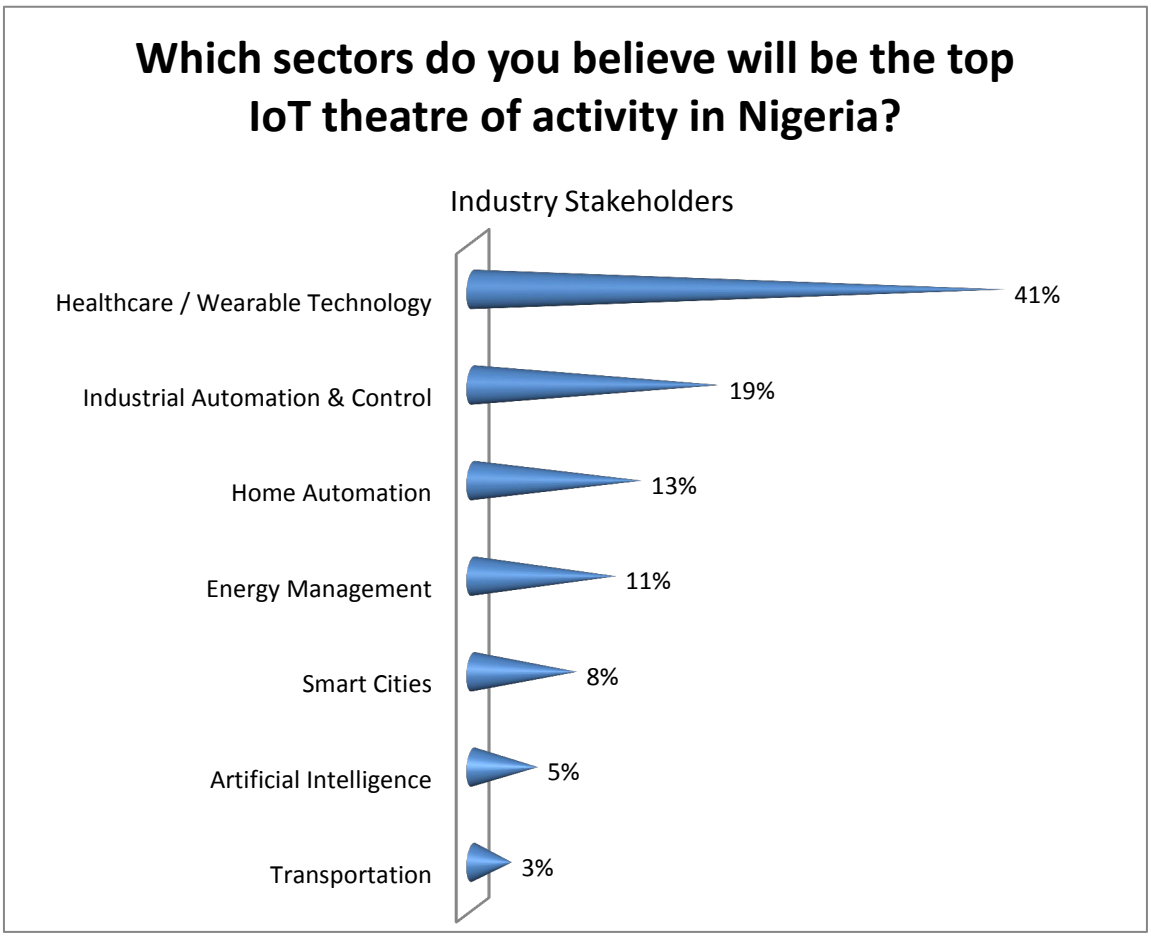
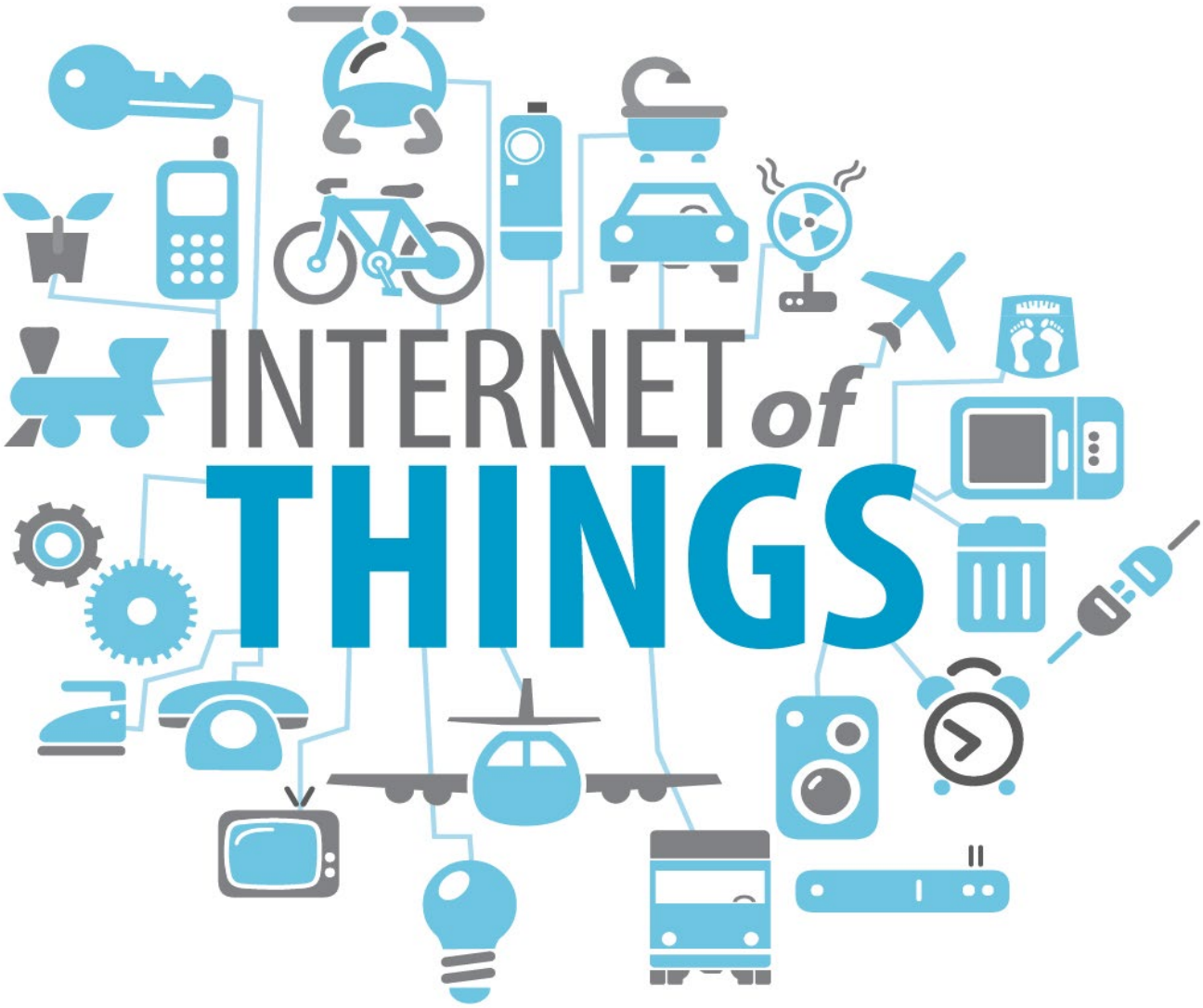


Figure 32: Projected IoT market verticals in Nigeria



CHAPTER FOUR

Conclusion and Recommendations

4.1 Conclusion

Digital technology will be a major driver of productivity, with successful economies depending on greater numbers of digitally skilled workers than has previously been the case. For Nigeria to successfully take her place in the emerging digital world, she must aim to achieve digital economy for 'everyone, in everyplace, and at all times,' creating equal access to opportunities and dealing with risks of exclusions. Ensuring that every person has the appropriate skills for an ever-growing digital and globalized world is essential to promote inclusive labour markets and to engender innovation, productivity and growth.

A holistic approach to digital economy development is necessary to maximize Nigeria's chance of attaining its digital potential. Rather than implementing multiple fragmented interventions, a coordinated and high-level cross-boundary approach that maximizes complementarities is needed to build an inclusive digital economy. This would ultimately spur the development of high-impact applications for health, education, e-commerce, agriculture, and social service delivery, among others, while mitigating exclusion, fraud, and cyber risks. Dealing with the digital economy requires a different flexible mind-set, collaborating among countries, sectors, public and private players.

Nigeria is currently capturing just a small fraction of its potential for digital development. Strategic investments and interventions are needed for Nigeria to develop a vibrant digital economy and kick-start its digital transformation.

First, the supply of broadband infrastructure is the necessary condition to expand access, which requires strategies for promoting the deployment of networks and appropriate solutions in underserved areas.

Second, with evidence that the spectrum is not used to its full capacity and that prices of devices and even low-priced data services are not affordable to

most Nigerians living under the poverty line, the Government needs to find ways to support the reduction of these costs, provide additional complementary public access and stimulate demand by addressing awareness and attractiveness issues.

Third, as a cross-cutting issue, the Government needs to design policies and interventions to mitigate the risks of skewing the benefits of broadband toward the well-educated and wealthy, which entrenches the digital divide and inequalities, and instead they should ensure that investments in technology benefit the bottom of the pyramid.

Security and Privacy of IoT Devices

Nigeria is only realizing a small part of the potential of its digital platforms. Some of the recommendations and next steps for Nigeria are:

- Remove the overlap of responsibilities between the different entities responsible for the regulation of the ICT sector in Nigeria;
- Review procurement policies and practices in order to ease access to public procurement for local companies;
- Build core capacity on Internet-era skills, focusing on teams responsible for the procurement, development and maintenance of digital services;
- Prioritize citizen-centric digital services and improve QoS monitoring;
- Promote bottom-up interoperability;
- Implement the Strategic Road Map for a digital ID system in Nigeria; and
- Provide special support to grow ICT hubs in Nigeria.

Financing Tech-Start-ups

The following are necessary to support the development of digital entrepreneurship in Nigeria:

- Legal, regulatory and institutional reforms;
- The pipeline of digital entrepreneurs must be strengthened;

- Early-stage funding needs to be de-risked and institutional investors incentivized to invest; and
- Markets for digital products and services must be strengthened. Nigeria's legal and regulatory framework must be assessed and structured to ensure that it can support the development of a digital economy.

To ensure the effectiveness of reforms, it will be critical to strengthen the institutional structure, collect and assess data on digital entrepreneurs, update the legal framework for private equity investment, and allow for the introduction of innovative financing mechanisms. It will also be critical to foster collaboration between ecosystem players, including digital entrepreneurs, innovation hubs, academia, big corporations, investors, and the Government, and to develop a Monitoring and Evaluation framework (M&E) for innovation hubs in partnership with the private sector.

The Government could play a catalytic role for early-stage investments in digital ventures by exploring avenues to help de-risking the market. It will also be essential to increase the scale of early-stage funding for digital entrepreneurs and incentivize institutional investors to invest in public and private equity markets. Markets for digital products and services can be strengthened by facilitating the provision of services to large corporations by start-ups with innovative products/services, supporting technology adoption in strategic industries and facilitating the inclusion of digital entrepreneurs in the provision of public services.

Improving Nigeria's Tech Ecosystem

Ensuring that every person has the appropriate skills for an ever-growing digital and globalized world is essential to promote inclusive labour markets and to engender innovation, productivity, and growth.

The following measures could be introduced in Nigeria to expand digital skills.

- Leverage the Smart Nigeria Digital Economy Project, using it to improve Government coordination, explore innovative ways of including digital skills in the wider curriculum and scale up private sector–led initiatives;

- Formalize the entrepreneurial link between ICT and business studies within and beyond higher education, so digital entrepreneurship and skills are seen by both males and females as a viable livelihood; and

- Improve virtual economy awareness in Nigeria, making the country a hub for microwork and elancing leveraging initiatives such as Click-On Kaduna, and Nigeria's current ranking in Africa with regards to microwork.

4.2 Recommendation 1

Each of the challenges highlighted by this Study can be overcome, through the actions of all stakeholders working in tandem, as follows.

Challenge	Recommendation
Data and Privacy	Strengthen accountability for IoT security and privacy by providing well-defined responsibilities and consequences for inadequate protection; Ensure that users can provide privacy permissions in a way that is simple to understand and implement; Encourage data portability by avoiding vendor lock-in; support for interoperable open standards would enable users to have more control over their data making it more readily portable to other services; and Discourage binding Government data or citizens' data to specific proprietary solutions.
Security and Safety	Remove uncertainty by clearly assigning liability on those that are most able to exercise control over the security of a product or service. IoT manufacturers and importers should be liable for safety and security defects in their products; Encourage security as a component of all stages of the product lifecycle, including design, production and deployment. Strengthen the ability of stakeholders to respond and mitigate IoT-based threats; Foster a culture of security among key stakeholders, including ISPs, that extends beyond their own interests, to the Internet and its users; Encourage information sharing, including threat mitigation techniques; and Provide support for computer security incident response teams and cybersecurity training and reference resources for new players in the IoT market.

Guidelines	Provide clear guidelines requiring IoT providers, developers, and manufacturers to protect against known vulnerabilities by ensuring reporting mechanisms are in place, supporting their products and systems with security patches and updates; Encourage certification schemes by which an organization signals that a product, service, or system has passed a set of quality or performance tests; Promote the use of Industry-accepted security risk assessment techniques before IoT products and services reach the market; Encourage IoT manufacturers and suppliers to use independent security experts to undertake certification assessment; Support the development of tools and processes to strengthen security risk analyses (e.g., through funding research); and Promote on a federal level the use of frequently reviewed and commonly accepted security best practices and guiding principles to guide the design, deployment, and use of IoT devices and services.

Spectrum	Promote internet and data-infrastructure growth through the expansion of both wireless and wireline infrastructure, and remove barriers to datacentre development;[98] Ensure that the mobile internet is available throughout the country; and affordable without undue costs; and relevant to users based on language and content; Ensure that sufficient spectrum is available to meet new demand and ensure that congestion does not throttle demand; Stimulate the deployment of IPv6 as an enabler to the IoT. With the current address depletion scenario, deployment of IPv6 is inevitable and promoting its transition is therefore paramount; Broaden broadband penetration everywhere and roll out 5G networks in urban high-density areas; Activate private sector networks for public problem solving by deploying such a scheme as training programmes on information and network security not only for Government workers but also for SMEs who cannot easily afford the costs; Different elements of the IoT, from machines to sensors, need a variety of spectrum resources that is fit for purpose. NCC should assess future demands for spectrum and review the mechanisms by which spectrum could be made available for a range of uses, including for the IoT; and Evaluate spectrum resources for the capacity to meet both current and future IoT needs.
Policy and Regulation	Adopt a collaborative, multi-stakeholder approach to IoT policy discussions and formulation; Strengthen consumer protection by ensuring personal data collected or used by IoT, especially sensor data

[98] **www.internetsociety.org/policybriefs/iot**

	are protected by privacy and data protection laws; Facilitate better security and privacy by clarifying how existing privacy, data protection and consumer protection laws apply to IoT; Similar to the prohibition of misleading representations about product safety, companies should also be prohibited from making misleading or deceptive representations about the security of their IoT products or services. Retailers should also share responsibility and not sell IoT products with known critical safety and security defects; Develop stronger procurement practices for IoT devices, platforms, and services that emphasize adherence to best practices in security and privacy; Require IoT suppliers to obtain third-party certifications or trustmarks as part of procurement policies; Mandatory use of Industry-accepted tools for testing IoT in evaluation processes for procurement; Develop policies and regulations transparently and prioritize the interests of users; Consider a sectoral approach to regulation. For example, regulatory tools that may be appropriate to the healthcare sector may not be as useful in the consumer device sector, where attributes like fault tolerance may not be as crucial to developing a safe product; Develop policies with to influence the IoT ecosystem to promote better security practices, rather than to mandate specific technical solutions; and Evaluate and assess existing policies and practices to see if they are suitably supportive of the IoT and do not constitute unintentional barriers to potential IoT benefits.

Sensitization	Support and engage in education and awareness campaigns to stimulate consumer demand for IoT security; Galvanise consumer groups in the development, implementation, public education and evaluation of IoT security; Accelerate the development of the IoT ecosystem through progressive market stimulation such as increasing market clarity and promoting entrepreneurship; and Promote skills to maximise opportunities in the labour market and support workers whose tasks become displaced by IoT-enabled systems.
Standardisation	Promote the use of global technical standards for the IoT developed by standards-setting bodies or Industry consortia because standardisation plays a key role in the development of an interoperable IoT ecosystem and is essential for stimulating the emergence of new systems, boosting innovation and reinforcing competitiveness;[99] and Encourage interested stakeholders to work together on the development of open, consensus-based standards that support interoperability.

Table 10: Recommendation 1

[99] THE INTERNET OF THINGS: SEIZING THE BENEFITS AND ADDRESSING THE CHALLENGES;

4.3 Recommendation 2

	Recommendations	Benefits
1	The 37 Federal Government-owned TICs should be restructured to operate on public-private partnership (PPP) model. The role of Government should be strictly regulatory and provisioning of enabling environment for entrepreneurship to thrive.	Private sector organisations would engender optimal performance in the technical incubation process. The inventions, innovative products and other creative designs of the SMEs currently domiciled at the existing TICs would receive aggressive private sector-driven push for adoption by large companies and multinationals to be commercialised and promoted both locally and internationally.
2	Universities and polytechnics should be encouraged to actively get involved in establishing and operating incubation hubs within their institutions. Every university and polytechnic should have at least one multi-discipline innovation lab that transitions prototypes to products.	Science, technical and engineering students in universities often have some of the best prototypes for their final year projects. Most of these prototypes can solve real Nigerian problems; but lack of competence and resource to turn them into marketable products consign them to prototypes in perpetuity.
3	Multinational companies, especially foreign-registered ones, should be required by law to establish incubation centres at their host communities as part of their Corporate Social Responsibility (CSR) programmes.	This is better than short-lived palliatives like charity or cash gifts for settlement of restive youths and has a greater prospect of mitigating political tension and promoting economic and environmental sustainability.

4	Local large scale corporations should be incentivised by the Federal Government to set up manufacturing and incubation labs that will also double as research, development and training centres in the country. NGOs and the private sector should be encouraged to get involved in establishing technical incubators in their areas of specialization across the country, with those in rural areas receiving enhanced Federal and State Government incentives.	For example, an automotive hardware training and incubation centre from Innoson Motors will grow the automotive Industry in Nigeria by leaps. The Tony Elumelu Entrepreneurship Programme (TEEP) is an example of how Nigerian companies can empower budding entrepreneurs in different sectors of the economy.
5	There should be structured research collaborations among Government agencies such as National Office for Technology Acquisition and Promotion (NOTAP), Raw Materials Research and Development Council, National Agency for Science and Engineering Infrastructure (NASENI), Federal Institute of Industrial Research Oshodi (FIIRO), Projects Development Institute (PRODA) among others.	Such platforms would bring stakeholders, investors and entrepreneurs together to make technical incubation outcomes useful for economic growth and entrepreneurship development.
6	Federal Government should empower the private sector by brokering partnerships with fab and fabless[100] companies as a way to boost knowledge-transfer in the shortest time possible.	Fabless semiconductor companies and fabrication plants are the two levels to the production of minuscule electronic components and are instrumental to developing the electronics-related hardware Industry of any economy.

[100] https://en.wikipedia.org/wiki/Fabless_manufacturing.

7	The Federal and State Governments should collect data on digital entrepreneurs and technology-enabled firms and conduct a technology adoption survey to systematically assess the firm-level barriers to adoption of digital technologies. .	This assessment will provide a basis for need-based development of Government policies and programs, and evidence for consultations with ecosystem stakeholders. This information will be a public good that allows digital entrepreneurs to better understand needs and constraints of their potential clients in internal markets and develop customized products for different client segments. It can also inform the design of programs of innovation and incubation hubs and other ecosystem enablers.
8	Government should conduct a review of its TICs and other related programs that target digital entrepreneurship in Nigeria and develop a Monitoring and Evaluation framework (M&E) in partnership with the private sector.	Performance data will promote competition among incubation hubs and improve resource utilization. It will also help identify good practices and scale up the most impactful models. This information will be critical to assure effective design and implementation of new university-based incubators that the Government is planning to set up across the six geopolitical zones.[101]
9	There should be better collaboration between eco-system players including digital entrepreneurs, innovation hubs, academia, big corporations, investors, and the Government.	The Government could play an important role in facilitating the digital entrepreneurship ecosystem by providing the platforms for public-private dialogue and incentives for collaboration. However, successful implementation of these initiatives will depend on ownership and participation of the private sector. The first step in that direction could be in helping the digital Industry to self-organize by supporting the capacity of digital Industry associations, providing forums for Industry dialogue, showcasing success stories of digital ventures, and providing awards to digital entrepreneurs to increase their visibility.

[101] https://weetracker.com/2018/08/10/the-nigerian-federal-government-to-spend-ngn-749-mn-on-incubation-centers/

10	Explore avenues to de-risk and scale up early-stage funding for digital entrepreneurs.	The Government could play a catalytic role for early stage investments in digital ventures by helping to de-risk the market. There are a range of options available based on international experiences, including mezzanine financing, guarantees, and fund-of-funds that invest alongside seed and early-stage investors that mitigate the exit risks to investors in a shallow Nigerian secondary market. Whatever solution is employed will need to be implemented in a transparent manner, with the private sector in the lead role, to eliminate the potential for market distortions prevalent in existing solutions.
11	Support mechanisms to facilitate provision of services to large corporations by start-ups with innovative products or services.	To promote the linkages with large buyers, the Government should help to address the following key challenges of Nigerian digital start-ups: ▪ the information gap, by providing matchmaking services between start-ups and large corporate firms; ▪ the capabilities gap, through upgrading programs that improve management and employee skills, quality control and technology; and the challenge of informality by lowering the administrative barriers to formalization. These initiatives will help to connect large corporations and multinationals in Nigeria with innovative start-ups locally.

Table 11: Recommendation 2

4.4 Recommendation 3

	Challenge Area	Recommendation /KPI
1	**Infrastructure**	Deploy regulatory efforts to encourage infrastructure sharing and open access to critical infrastructure to allow faster deployment and greater rural push in middle and last mile connectivity; Effective infrastructure sharing and open access wholesale would bring broadband to rural areas more quickly by limiting duplication of infrastructure and redirecting resources to underserved communities; and Monitor QoS metrics consistently and enforce infrastructure quality standards to solve QoS issues that prevent some operators from using their competitors' networks.
2	**USPF**	Raise visibility of the Fund and promote transparency and accountability to accelerate infrastructure development in underserved areas; and Establish a 'Pay or Play' mechanism, whereby operators can choose if they want to contribute financially to the Fund or invest directly in projects themselves and guarantee specific universal access targets in exchange for relief from USPF levies.
3	**Private Sector**	Use innovative solutions to mobilize substantial private sector investment and expedite development of broadband infrastructure in underserved areas; Promote innovative Public Private Partnership with competitive awards of subsidies to private operators to support

		infrastructure development in areas where market forces alone are insufficient to provide adequate broadband coverage; Activate Government pre-purchase of international bandwidth, which, if well-advertised, would reduce investment risks for private operators; and Consider preferential taxation (e.g. reduction of annual telecommunications fees, income tax holidays, lower fees for deployments, tax exemptions on data devices and equipment) for providers who agree on specific universal access targets.
4	**Spectrum**	Optimize spectrum market mechanisms to promote more efficient spectrum use; Ensure liberal spectrum re-farming and/or trading regime for greater flexibility and reduce need for new spectrum auctions; and Promote greater transparency on spectrum allocation processes to encourage private investment.
5	**Intra/inter Agency Coordination**	Strengthen coordination between the different agencies that govern ICT policy, regulation and implementation, and consider streamlining the institutional and regulatory framework; Establish a technical working group to bring all ministries/agencies involved in the ICT sector together to avoid overlaps, and to better coordinate future interventions; Provide more clarity on who is regulating the last mile segment of the fixed broadband market and what regulations should govern ISPs' operations;

		Establish a coordinated policy approach to provide public access. A number of programs providing access points (CRC, RUBI, incubators, etc.) are being implemented by different agencies with different resources and priorities. The Government should try to build on synergies to improve program efficiency and generate economies of scale; and Consider merging some agencies/regulators to adapt to increasing technological convergence.
6	**Affordability**	Promote affordability of broadband-enabled devices and widen opportunities for individual access; Reduce or eliminate excise duties and other taxes on feature and entry-level smartphones, tablets, or laptops; Introduce grants or offer low or zero-interest loans for their purchase, with a targeted approach to prioritize women and marginalized populations to reduce digital gaps; and Provide broadband equipment to educational institutions at cost or via subsidies.
7	**Community Access**	Expand communal broadband access to connect the unconnected as citizens in underserved communities mostly do not use broadband because they have no access, cannot afford it, or are not aware of its benefits; Construct more Community Resource Centres by exploring partnership

		opportunities with private sector actors that could use these centres to market their activities and enrol customers (e.g. for mobile money); and Leverage the Rural Broadband Initiative network to provide connectivity to underserved communities.
8	**Right-of-Way Regulation**	Enforce harmonized rights-of-way policies for accessing public infrastructure and taking advantage of future civil works projects for cross-sector infrastructure sharing; Put regulation in place to compensate landowners for use of property to build digital infrastructure in an environmentally safe manner, reducing equipment vandalism and theft; and Enforce the fixed national rates per meter for laying fibre network and monitor and penalize States choosing to fix their own pricing.

Table 12: Recommendation 3

Appendices

APPENDIX ONE: TERMS OF REFERENCE

Section 6. Terms of Reference

PROPOSAL FOR A CONSULTANCY STUDY ON NEXT GENERATION NETWORKS (NGN) AND INTERNET OF THINGS (IoT)

1.0 INTRODUCTION

Next Generation Network (NGN) is a packet based network able to provide Telecommunication Services to users and able to make use of multiple broadband, quality of service enabled transport technologies in which service related functions are independent of the underlying transport related technologies. Simply put, it enables unfettered access for users to networks and to competing service providers and services of their choice. The ability of NGN to support voice, data and video has ushered in the internet of things (IoT).

The internet of things (IoT) is an emerging topic of technical, social and economic significance. It refers to scenarios where a network connectivity and computing capability extends to objects, sensors and everyday items which are not normally considered as computers, allowing these devices to generate, exchange and consume data with minimal human intervention or interference. Technically, IoT refers to the use of intelligently connected devices and systems to leverage data gathered by embedded sensors and actuators in machines and other physical objects. Devices in this context, range from people, household appliances, animals, cars, servers, and park benches to any conceivable object with smart functionalities such as Information Storage, Information Collection, Communication, Information Processing and Performance of Actions.

IoT has the potentials to positively revolutionize the way devices (things) which have sensors embedded in them are being combined with internet connectivity and powerful data analytical capabilities that can transform the way we work, live and play. IoT is expected to spread rapidly over the coming years and this convergence will usher a new dimension of services that improve the quality of life of consumers and productivity of enterprises, unlocking an opportunity for users. Several studies reviewed projects the impact of IoT on the internet and economy are impressive, with some anticipating as many as 100 billion connected IOT devices and a global economy impact of more than $11 trillion by 2025. However, the impact of internet of things raises significant challenges that could stand in the way of realizing its potential benefits. Prominent among these concerns range from;

- Security of internet connected devices
- Technical challenges for standards
- Policy and development challenges

Internet of things is still in its infancy as some of its concepts and technologies that would enable its full implementations have not yet become household concepts. It will take a gradual process before the concepts of autonomous embeddable device to device communication – (the bedrock for IoT) become part of the daily lives of the internet users but until then, the IoT will first find its acceptances in mini networks, in industrials, household appliances, etc. In the long run, when it eventually gains acceptance and full implementation, there is likely going to be a boom in certain markets involving certain key sectors of the economy.

To this regard, Nigeria should find ways of empowering the local manufacturing sector to leverage on this emerging trend. This could potentially create employment for the growing number of technologists, take

care of local peculiarities and drive local content thereby saving the country its hard earned foreign exchange and reducing our dependence on foreign goods and services. Similarly, with IoT, It is projected that billions of devices will be online, consequently network connectivity will be required by these devices to communicate. More device connectivity means more subscription for data services from telecommunications providers, and thus more revenues for the government. Nigeria telecommunications industry needs to be ready for this massive increase of data services and all the attend consequences that may come with it. Regulations of IoT equipment, services and security should be of utmost importance as well.

3.0 OBJECTIVES /TERMS OF REFERENCE (ToR)

The main objective of the study is to provide the Nigerian Communications Commission (NCC) with a comprehensive report on ways to accommodate and accelerate the development of IoT in Nigeria. The study therefore, will have the following specific objectives/terms of reference (ToR)

- Suggest ways to encourage the use of IoT at all levels; Government agencies, corporate bodies, individuals taking into cognizance existing resources such as frequency and infrastructure availability. This is expected to increase broadband penetration levels in the country.
- Suggest frameworks and models for setting up of technology incubation centers in Nigeria which will ultimately help promote the development of IoT devices and drive its development and deployment.
- Suggest new revenue streams that can be used to stimulate growth of Nigeria's tech-ecosystem.

- Suggest policy guidelines that can improve security and piracy concerns in using IoT.
- To identify regulatory incentives for deployment of IoT by cooperate bodies such as utility companies, logistics amongst others
- To suggest regulatory incentives for IoT friendly service providers.
- Show how IoT can improve the economic status of Nigeria.
- Identify its current and future uses of IoT across the globe.
- Make recommendation on suggested amendments to existing licenses and/or regulations of the Commission to support the growth and implementations.
- Identify any ethical issues regarding IoT.
- Identify infrastructure needs and gaps for the implementation of IoT.
- Nigeria customer needs and expectation from IoT.
- Identify competitive market forces requiring IoT.
- Determine if there is a need and market for (IoT) in Nigeria.
- To produce a comprehensive study on the best models, products and segments of (IoT) that will likely thrive in Nigeria.

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2.0 SCOPE

The scope of the study will cover the entire thirty-six (36) states of the federation and Abuja in seeking ways to stimulate the development, deployment and use of IoT services. This will be done under the following headings:

- IoT Devices: The study shall suggest ways to create an enabling environment that will stimulate production of IoT devices that are of international standards and can compete globally. This is to push for local content in the telecommunications industry.
- Improving Nigeria's Tech Ecosystem: the study is expected to come up with pragmatic approach towards setting up of technology incubation centers/ assisting tech-startups to scale across Nigeria.
- Security and privacy of IoT devices: IoT devices, applications and services generates a vast amount of data about their users. This is potentially dangerous if not properly guarded. As such, this study shall suggest policy guidelines that will ensure security and privacy of IoT service in Nigeria.
- Financing Tech-startups: One major problem hindering technological advancement in Nigeria has been lack of finance. Banks are reluctant to buy into ideas of bright Nigerian innovators. Similarly, Nigerian government revenues are insufficient to fund a dynamic and proactive Tech-ecosystem. This study in this respect is expected to identify new revenue streams for government which can be used to finance Tech-startups profitably.

3.0 DELIVERABLES

The Consultant will deliver the following documents in accordance with agreed timelines as indicated in the work plan:

1. An inception report to be submitted within four (4) weeks of acceptance of Letter of Award. This inception report will detail the study approach/methodology and work plans with timelines including review meetings, in-house or out of office trainings where necessary, presentation periods following the submission of draft interim/progress reports and draft final reports. In the event that the inception report is unacceptable, the Commission reserves the right to cancel the award.
2. Interim/progress report before and after the completion of field survey.
3. Draft final report.
4. Final report.
5. The consultant shall submit five (5) copies of each of the approved final report and two electronic copies in Microsoft Office software formal.
6. A publishable executive summary of the final report.

4.0 TIME FRAME (or DURATION)

The study shall be executed within twenty (20) weeks effective from the date of award. An Inception Report must be submitted within four weeks of acceptance of award.

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5.0 PAYMENT

1. 25% of agreed consultancy project sum as first installment upon acceptance of Inception Report.
2. 40% of agreed consultancy project sum as second installment on submission of Interim/Progress Report after completion of field survey and the Draft final report.
3. 35% being full and final payment of the agreed consultancy project sum on acceptance of the Final Report.

6.0 ADMINISTRATIVE ARRANGEMENTS AND RESPONSIBILITIES

While this study is underway the consultant shall;

1. Report directly to the Department of Research and Development of the Commission and shall be responsible for alerting the Commission on all major issues pertinent to the successful execution and completion of the study.
2. The consultant is expected to be available until the completion of the studies.

7.0 CONDUCT OF THE CONSULTANT

1. The Consultant shall be expected to carry out the assignment with the highest degree of professionalism and integrity.
2. The Consultant shall conduct their duties in an open and transparent manner and shall not hinder nor prevent the Commission from executing this or any other transaction included as part of industry development.

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3. The Consultant will study all the guidelines and policies of the Commission with respect to the industry development initiatives and will be expected to ensure that the transaction is concluded with very strict adherence to such policies and regulations.

4. The Consultant shall not take any material decision concerning this study without the express permission of the Commission.

5. The Consultant shall not discuss, publish, or reveal any information regarding the study without the Commission's approval.

APPENDIX TWO: ACRONYMS

AI	Artificial Intelligence
BoI	Bank of Industry
CSR	Corporate Social Responsibility
EPC	Electronic Product Code
ESP	Electronic Service Provider
FCT	Federal Capital Territory
FIIRO	Federal Institute of Industrial Research Oshodi
HH	Households
HVAC	Heating Ventilation and Air Conditioning
ICT	Information Communication Technology
ID	Identification
IoEyes	Internet of Eyes
IIoT	Industrial Internet of Things
IoMT	Internet of Military Things / Internet of Medical Things
IoT	Internet of Things
IPv6	Internet Protocol Version 6
ISP	Internet Service Provider
ITU	International Telecommunications Union
KPI	Key Performance Indicators
LPAN	Logical Processing Area Network
M&E	Monitoring and Evaluation
M2M	Machine-2-Machine
MDA	Ministry, Department, Agency of Government
NAFDAC	National Agency for Food and Drugs Administration and Control
NASENI	National Agency for Science and Engineering Infrastructure
NBTI	Nigeria Board for Technical Incubation
NCC	Nigerian Communications Commission
NFC	Near Field Communication
NGN	Next Generation Networks
NIBSS	Nigeria Interbank Settlement System
NITDA	National Information Technology Development Agency
NLP	Natural Language Processing
NNPC	Nigeria National Petroleum Corporation
NOTAP	National Office for Technology Acquisition & Promotion
NRA	National Regulatory Agency
NYSC	National Youth Service Corps
OEM	Original Equipment Manufacturer
PDT	Project Delivery Team
PIU	Project Implementation Unit
PoS	Point of Sales
PPP	Public Private Partnership
PRODA	Projects Development Institute
PST	Project Supervision Team
PSU	Primary Sample Unit
PVC	Permanent Voters Card

QoS	Quality of Service
RFID	Radio Frequency Identification
SaaS	Software as a Service
SME	Small Medium-scale Enterprise
SRD	Short Range Device
SSU	Secondary Sample Unit
TIC	Technical Incubation Centre
ToR	Terms of Reference
TSU	Tertiary Sample Unit
UAV	Unmanned Aerial Vehicle
VOIP	Voice over IP
UID	Unique Identification

APPENDIX THREE: INDUSTRY STAKEHOLDERS SAMPLED

	ORGANISATION	UNIT:	CATEGORY
1	MoCDE	NCC	Government, Policies, Regulations
2	Nigerian Communications Commission (NCC)	Internet Governance Unit	
3	National Agency for the Prohibition of Trafficking in Persons (NAPTIP)	Public Enlightenment Department	
4	Federal Ministry of Youth and Sports Development	Education and Youth Development (EYD)	
5	Nigeria Police Force (NPF)	Research & Development Department	
6	Federal Ministry of Education	Basic and Secondary Education Department	
7	Federal Ministry of Science and Technology	Planning Research and Policy Analysis	
8	National Information Technology Development Agency	Standard Guidelines and Frameworks Department	
9	Federal Ministry of Justice	Citizens' Rights Department	
10	MTN	Corporate Communications Department	Telecom Providers
11	Airtel	Corporate Affairs	
12	9-Mobile	Corporate Affairs	
13	Glo	Corporate Affairs	
14	Computer Society of Nigeria	Head Office	Professional Bodies
15	Computer Professionals of Nigeria	Head Office	
16	Nigeria Internet Regulatory Agency	Head Office	
17	Save the Children Nigeria	Head Office	NGO
18	Nigeria Ministry of Women Affairs and Social Development		

19	AfriOne		Original Equipment Manufacturers
20	Tecno		
21	Manufacturers Association of Nigeria (MAN)		
22	African University of Science & Technology		Academia
23	University of Ilorin		
24	University of Lagos		
25	Jumia		Online Retailers
26	Jiji		
27	Opera		Content & internet Service Providers
28	Mentor		

Table 13: List of Industry Stakeholders Sampled

Internet of Things – Questionnaire for Individuals

1. Please Select Your Age Group

- Under 12
- 13 - 18
- 19 - 25
- 26 - 35
- 35 - 45
- 45 - 60
- 60+

2. What Is Your Gender?

- Female
- Male
- Other

3. Which LGA and State Do You Currently Reside In?

5. Which of the Following Devices Do You Use That Are Internet-Connected? (Select All That Apply)

- ☐ Laptop Computer
- ☐ Health-Related Devices
- ☐ Radio
- ☐ Kitchen Appliances
- ☐ Wearables Accessories
- ☐ Desktop Computer
- ☐ Computer Tablet
- ☐ Smartphone
- ☐ TV
- ☐ Gaming Consoles

6. One focus the Internet of Things has in our everyday life includes efficiency and comfort. Google has recently brought out a device called "nest" thermostat, a device that can cool or warm your house based on your habits. It learns the way you use the device and remembers the temperature you place it on, automatically altering it. After further use, this device would also be able to detect your mood and emotions then adjust the temperature to suit it even before you step into the room. It is estimated that devices such as these would become available as soon as 2030. Would you use such a device?

- ○ Yes
- ○ No
- ○ Not Sure

7. Privacy and security are some of the major concerns with the impending era of the Internet of Things. Data and information such as spending habits, Internet browsing, and multimedia messages collected from users are placed under one network, would this affect the way you use such IoT devices?

- ○ Yes
- ○ No
- ○ Not Sure

8. Many people around the world today have instant access to information at the touch of a button. Do you think the IoT will make society more or less intelligent?

- More Intelligent
- Less Intelligent
- Not Sure

9. Up to 50 billion devices would be connected to the Internet of Things in 2020. Reflecting on your lifestyle and daily habits, would you be comfortable conforming to living in a world governed by the IoT?

- Very Comfortable
- Comfortable
- Not Comfortable

10. Does the IoT currently make your life easier?

- Yes
- No
- Not Sure

11. If yes how does it make your life easier?

- More Productive
- More Manageable
- More Connected
- Other (please specify)

12. What would you like to be IoT capable?

- Vehicles (self-driving)
- Parking
- Intelligent Public Transport (no Driver)
- Waste Management
- Domestic Appliances

13. Which Of the Following Do You Consider As A Risk of IoT? (Please Select All That Apply)

- [ ] Data Storage
- [ ] Security
- [ ] Lack of Standards

14. Would You Use a Type of Universal Remote?

- ○ Yes
- ○ No
- ○ Not Sure

15. If Yes What Would You Use as a Universal Remote?

- [ ] Mobile Phone
- [ ] Wearable Tech
- [ ] Embedded Tech
- [ ] Other (please specify)

16. Do you think that the IoT will make most human job redundant with their automation?

- ○ Yes
- ○ No
- ○ Not Sure

Thank you for taking part in this survey

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Internet of Things – Questionnaire for Industry/Policymakers

1. Your Organisation's Affiliation

- ○ Academia
- ○ Industry
- ○ Public (Org, Gov, Etc.)
- ○ Research Institute
- ○ Telecommunication
- ○ Original Equipment Manufacturer
- ○ NGO / Third Sector

2. Which of the following terms are you familiar with?

- ☐ Internet of Things
- ☐ Artificial Intelligence
- ☐ Augmented Reality

3. Out of the following, what do you feel is the most important aspect to consider when deploying IoT solutions?

- ☐ Security
- ☐ Communication Reliability
- ☐ Ecosystem
- ☐ Device Reliability
- ☐ Ease of Data Review/Analysis

4. What is your key concern regarding IoT?

- ☐ Connectivity
- ☐ Interoperability
- ☐ Ecosystem
- ☐ Security

5. Which sectors do you believe will be the top IoT theatre of activity in Nigeria?

- ☐ Industrial Automation & Control
- ☐ Home Automation
- ☐ SMART Cities
- ☐ Artificial Intelligence
- ☐ Energy Management
- ☐ Transportation
- ☐ Wearable technology
- ☐ Other

6. What do you believe is the most common type of sensor technology?

- ☐ Environmental
- ☐ Motion
- ☐ Image
- ☐ Health Monitoring
- ☐ Audio

7. What is the main reason for your organisation deploying an IoT solution?

- ☐ We Are Innovators
- ☐ Because There Is a Need in the Market
- ☐ To Simplify and Improve People's Lifestyle
- ☐ Iot Strategy Is Our Business Objective/Focus
- ☐ We Are Following the Market Trend

8. Who do you believe should own the data gathered by IoT devices?

- [ ] User Whose Data Is Gathered
- [ ] Company Who Implements IoT System
- [ ] External Governing Body

9. What factor do you think would most accelerate the benefits of the IoT? (Choose Only One)

- ○ Interoperability
- ○ Ease of Development
- ○ Need For Open Standards
- ○ Connectivity Standards
- ○ Need For Data Privacy Policy
- ○ Adoption by Public Sector
- ○ Energy Consumption

10. How likely would your organisation be to take on the lead role of building an IoT product itself?

- ○ Very likely
- ○ Likely
- ○ Unlikely

Thank you for taking part in this survey

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APPENDIX SIX: BIBLIOGRAPHY

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