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# IoT Based Patient Health Monitoring System: The Way Forward for Patient Health Monitoring in Nigeria

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**Abstract**

*Patient health monitoring is a process of observing vital signs of patients with the aim of forecasting ailments to expunge them thus, preventing acute complications. In many African countries Nigeria included, lack of proper patient health monitoring has become a menace. Statistics shows that more than 40% of adults in this region are estimated to have manageable diseases like high blood pressure, heart diseases and hypertension. Most of these patients have met with different disabilities and in some cases untimely death due to lack of proper patient health monitoring and insidious manual system of monitoring which is utilized in this region. Nevertheless, there is need to proffer solution to this problem to help in early detection, monitoring and treatments of these diseases. In this paper, a system architecture for proper monitoring of patient's health using internet of things (IoT) as an approach is presented. It involves reading real time data from sensors attached to patients. This data is sent to a local device via communication channels (Bluetooth/Wi-Fi technology) and then transmitted to the IoT server via the internet using a gsm/gprs module thus allowing for quick medical access and response where necessary.*

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## 1. Introduction

Good health is a very important piece in the human puzzle of life, as the popular saying goes "health is wealth; a healthy man is a wealthy man" hence having high-quality health and good judgment are considered as the greatest life has to offer to humanity [1]. Hence, it is of utmost importance for every human to see that he/she plays their role in improving and assessing their health status in order to stay hale and hearty.

In [2], it was stated that humans should have lifelong monitoring of vital signs that predict things like heart diseases, skin disorder and other ailments in order to eradicate them. One way to achieve eradication of diseases and ailments is to have one's health properly monitored.

Patient health monitoring is defined as the persistent supervision of the clinical examination conducted in lieu with set of rules guiding excellent clinical practice, typical operating actions and requirements [3]. The sole aim of monitoring patients' health is to observe if a particular proposed result or set of results has occurred in reality after a medical procedure or material has been applied by health professionals on the patients in order to satisfy the needs of the patients to become hale and hearty.

From a survey conducted by [4], it was reported that in every three adults worldwide, one has increased blood pressure – a situation that has accounted for half of all deaths from emanating from stroke and heart diseases.
In the report of [5], it was affirmed that of the over 56 million deaths recorded worldwide in 2015, in excess of 54 percent were caused by heart diseases and stroke which are classified as the world's major killers, accounting for a collective 15 million deaths in 2015. The aforesaid diseases have remained the foremost causes of death worldwide for the past 15 years. Deaths caused by diabetes rose to 1.6 million people in 2015, which was initially less than 1 million in 2000.
According to [6], hypertension is one of the most rampant non-communicable conditions in the world today. It was further declared that hypertension is accountable for an estimated 45 percent and 51 percent of deaths owing to heart disease and stroke worldwide. Of the six continents under WHO supervision, the African continent has the utmost predominance of hypertension which is projected at 46 percent of adults between the ages of 25 and beyond.
However in [7], it was affirmed that figures available have publicized that 70 percent of hypertensive patients embark on continuous usage of medications while the frequency of hypertension amongst Nigerians is in the range of 25 to 40 percent based on the area of locality.
In [8],it was made know that non-communicable diseases like the above stated which are categorized as chronic has resulted to untimely deaths of people and can be prevented with appropriate health management activities through monitoring of patients health. It was further stated that if monitoring of patient health situation is done with high quality coordination, the quality of care of people will improve drastically.
To this end, there is need for a system that helps to monitor patient's health in a bid to curbing the menace of untimely deaths.

Internet of Things(IoT) is a platform that allows for interaction to exist amongst substantial devices, vehicles, buildings, and other substances enclosed with electronics, software, sensors, actuators, and network connectivity which facilitates these objects to accumulate and trade data over the network of networks called internet as defined by [9].
However, these embedded IoT sensors can employ various types of network connections such as Wi-Fi (Wireless Fidelity), Bluetooth etc., and has been applied in different areas such as environmental monitoring, infrastructure management, transport and manufacturing.
The health sector is not left out in the wide application of IoT technology as wearable IoT tech is a fast rising area and is becoming popular in this regard. It consists of several devices, generally with its application extending over the following areas such as fitness, health and entertainment arenas. The major rudiments for wearable IoT technology are that the sensors and devices are particularly energy-efficient, requires low power consumption and petite-sized.
In this paper, we intend to propose a system for monitoring patients' health based on IoT in Nigeria.

In Nigeria, patient healthcare monitoring involves patients coming to the hospitals, clinics and other health facilities to be examined by medical personnel. On arrival at the health facility, patients spend substantial amount of time waiting at the reception or waiting room for examination which is to be carried by medical personnel and other allied health professionals and also patients on admission in the hospital closely monitored to see how they respond to treatments being administered to them as declared by [10].
However, there are 2 types of patients whose health are monitored namely; Incoming patients and Outgoing patients. Incoming patients are patients who visit the hospitals for healthcare services such diagnosis and treatment of ailments and diseases which are administered by medical personnel. These patients are sometimes admitted into a ward after examination based on the recommendation made by the medical doctor on duty. Outgoing patients are patients who had been admitted and now discharged based on the recommendation of the medical doctors, or patients referred to other health

facilities such as General hospitals, Specialist hospitals for better treatment and monitoring of patient's health.

In [10], it was further stressed that patient health monitoring is done at different levels in Nigeria health sector namely: Primary Healthcare (Local Government Level), Secondary Healthcare (State Government Level), Tertiary Healthcare (Federal Government Level) and Private Healthcare (Private Practice Level). With Nigeria practicing a three level government system, each of the level according the constitution of the country is obliged to take responsibility of the health sector at its level.
The Federal Government which is the highest level is expected to focus on tertiary and apex referral institutions such as the National Hospital, the Specialist/Teaching Hospitals and Federal Medical Centers.
The State Governments are expected to take charge of the secondary healthcare system i.e. the General Hospitals, Health Centres, State Universities Teaching Hospitals and state owned healthcare delivery facilities.
The Local Government takes charge of the primary healthcare system which major function is the supervision of local dispensaries, environment sanitation/protection and routine immunization etc.
Private healthcare is responsible for private practice healthcare system used at Private Hospitals, Private Medical Centres, Private Specialist/Teaching Hospitals and other privately owned healthcare facilities.

### 1.2 Patient Healthcare Monitoring at Primary Healthcare Level

In 1988, Nigeria launched the National Primary Health Care under the Military regime of General Babangida. The scheme initially was a joint effort of the three levels of government tailored to Nigeria's socio-economic and cultural background. The Primary health care focal point is the realization of health equity in order to create social sustainable policies that surpass the customary healthcare system. The primary objective is to make available healthcare to patients locally provided by health professionals who handle a wide range of psychological, physical and social issues instead of medical personnel who specialize in particular disease domain. Primary care services are speedily rising in both the developed and developing countries based on the escalating number of aged patients who are at a great risk of encountering chronic non-communicable disease such as diabetes, asthma, back pain, hypertension, anxiety, depression etc as reported by [11].

Towards achieving the vital goals of primary health care, [4] highlighted four essentials to accomplish this goal; the elements are:

- Increased participation of collaborators
- Incorporate health into all areas. pursue
- Coordinating healthy services according to people desires and surpassing their expectations
- Tracking joint models of policy discussion.

However, patients at this healthcare level get registered and gets an appointment card, and are examined by medical personnel who checks the blood pressure, body temperature and urine test and records observations in the patients file before been forwarded to the doctors who will further examine the patients based on observations pointed out in the patient's file. The doctors then make necessary recommendation by prescribing drugs to the patients, and then book an appointment which the patient will return to access the state of health after usage of prescriptions as affirmed by [10].
The monitoring of patient health is done when patient is within the health facility. If doctors observe that health situation of patient does not improve based on prescription of drugs on appointment day,

the doctor refers the patient to the General Hospitals, Health Centres, State Universities Teaching Hospitals and for better treatment and monitoring of health situation. The medical services rendered are most times free of charge. Drug prescribed are sometimes given out free of charge to patients if available in dispensary as stated by [11].

### 1.3 Patient Healthcare Monitoring at Secondary Healthcare Level

This type of healthcare is offered by medical and allied personnel who are experts in a particular field of medicine such as dermatologists, cardiologists etc and don't have express access to the patient. In line with the National health system policy, it is of essence that patients require a medical professional's referral from primary healthcare level to advance further to secondary healthcare. National health policy requires patients to get primary care professional's referral in other to proceed for secondary care. Depending on the country, health systems may impose a restriction on referral for a patient to take secondary care in terms of payment [12].

In [10], it was made known that based on referral from primary health centres, patients are assigned to specialist doctors on arrival at the hospitals after obtaining a patient card at the frontdesk of the hospital based on their ailment for proper healthcare treatment and monitoring. Doctors further examine the patients to ascertain the level of ailment of the patients, if situation is critical, the doctor recommends admission of patient for close monitoring and treatment or a caesarian section depending on the level of damage the ailment has caused the patient. The patients placed on admission are monitored by the nurses who checks patients on an hourly basis and documents observations of how patients respond to treatment and drug prescriptions administered in patient's file before being forwarded to the doctor for further assessment of patient.

Patients who are not admitted are given appointments to check back to the hospitals for medical checkup and monitoring. The discharged patients are also given appointments to check back to the hospital for assessment in order to monitor the health condition of the patient to see if there is any recurrence of ailment or improvement of health. Patients are charged for medical services rendered to them.

### 1.4 Patient Healthcare Monitoring At Tertiary Healthcare Level

In [12], this category of healthcare was described as dedicated type of healthcare that employs effective consultation typically for incoming patients and those based on recommendation from primary and secondary healthcare for superior medical examination and treatment in cases relating to surgeries (plastic, cardiac etc), treatment of burns, , cancer supervision, neurosurgery, complicated medical and surgical aid etc. The National Health System is the major giver of tertiary care which is administered in Regional and National Hospitals. Regional hospitals entertain recommendations from various district hospitals and act as training sites corresponding to the National referral hospital. These health facilities make available additional healthcare services and are operational 24 hours every day.

Based on recommendation from primary health and secondary healthcare centres, patients are assigned to doctors on arrival at the hospitals after obtaining a patient card at the front desk of the hospital based on their ailment for proper healthcare treatment and monitoring.
Doctors further examine the patients to ascertain the level of ailment of the patients, if situation is critical, the doctor recommends admission of patient for close monitoring and treatment or a caesarian section depending on the level of damage the ailment has caused the patient.
In [10], it was stressed that the patients placed on admission are monitored by the nurses who checks patients on an hourly basis and documents observations to see how patients respond to treatment

and prescriptions administered in patient's file before being forwarded to the doctor for further assessment of patient. The discharged patients are also given appointments to check back to the hospital for assessment in order to monitor the health condition of the patient to see if there is any recurrence of ailment or improvement of health. Patients are charged for medical services rendered to them.

### 1.5 Patient Healthcare Monitoring at Private Practice Level

This type of healthcare is provided by medical doctors, who own private clinics, specialist hospitals, private healthcare centres and doctors who are employed in private university teaching hospitals and other privately owned health facilities as declared by [12].
Here patients get registered and gets an appointment card, and are examined by medical personnel who checks the blood pressure, body temperature and urine test and records observations in the patients file before been forwarded to the doctors who will further examine the patients based on observations pointed out in the patient's file. Doctors further ask patient of any other complaints based on the observation recorded in the patient file.

The doctors then make necessary recommendation by prescribing drugs to the patients, and then book an appointment which the patient will return to access the state of health after usage of prescriptions. In the case, when it is observed that the health situation is critical, the doctor recommends that the patient be admitted for further examination and monitoring. The monitoring of patient health is done when patient is within and outside the hospital as avowed by [10].

For admitted patients, the doctor prescribes bed rest, drugs which is to be administered to patients. The doctor places the patient on an hourly based monitoring which carried out by the nurses on duty, to observe how patients are responding to treatment and drugs administered to them. After the hourly monitoring, the nurses document all observations in the patient file. Then during the doctor's ward to ward check on patients which is most times in the evening, the doctor is accompanied with the nurse who holds each admitted patients file, when the doctor checks the monitoring report filed by the nurse on which he examines the patients to ascertain the observations made. Sometimes patients withhold some information about their current state of health from nurses, here the doctor further ask patients of any side effects or any other feeling which has not be disclosed to the nurse. After examining the patients, the doctors then make more recommendation to bring about improvement of patient's health as stated in the work of [10].

For incoming patients, doctor prescribes drugs to patients and fix appointments for the patient to return for treatment and monitoring. On the day of appointment, if patients do not show up, doctor calls patients to find out why he/she missed appointment and reschedule another appointment. Days after the appointment, the doctor calls the patients regularly to monitor the state of health of patients and documents all information made available to him by the patients with the doctor recommending that in the case of any relapse in health, the patients should not hesitate to report to the hospital for further treatment and monitoring. For outgoing patients, the doctor also recommends as mentioned previously in case of any relapse or deteriorating state of health.

[10] further stated that manual approach of patient health monitoring practiced in Nigeria at all healthcare levels has issues which include; Patient monitoring can only be carried out only if the patient is physically present, There is problem of congestion of patients in the hospital wards, Inadequate medical personnel to attend to all patients, Insufficient medical equipment.

With the above mentioned issues, the growth in the IT in this part of the world has given rise for technology to be applied at various sectors in the country.

According to [13], Nigeria is an illustration of an emergent economy that is accepting IT systems in different sectors such as transport, manufacturing, businesses organizations and healthcare. This is owing to the speedily rising development in use of the internet by consumers. Internet utilization has amplified as a result of the growing use of IoT devices, which has recently turned out to be more reachable to a mostly young, old and educated population.

In [14] it was declared that in 2018, Nigeria had over 91 million internet subscribers and by 2020 it is estimated that the population of internet users will hit 134.2 million users of mobile phone internet. This number is estimated to exceed 187 million internet consumers by 2023. The internet infiltration showed a significant growth of 47.1 percent of the Nigerian population in 2018 and is expected to attain 84.5 percent by 2023. It was further stressed that Nigeria being one of the most populous countries in the world is ranked at the apex of the list of African countries based on the internet traffic through usage of mobile smart devices.

Hence, with large usage of internet users in Nigeria, Nigerians have been able to do virtually everything on the internet from shopping via e-commerce websites, renting taxis and motorcycles online for easy transportation to banking online (Finance) etc. However, despite the usage of internet in these aforesaid areas, it has not been fully maximized in the health sector in Nigeria particularly in the area of health monitoring. For this reason, there is need to see how Internet of Things (IoT) can be utilized in the health sector particularly in the area of patient healthcare monitoring in Nigeria which will serve as an alternative to the manual patient healthcare monitoring still been practiced at various healthcare levels in the country.

### 1.6 Internet of Things (IoT)

In [15], Internet of Things (IoT) was defined as the use of intelligently coupled devices and systems to control data assembled by implanted sensors and actuators in machines and other substantial objects. However, IoT systems allow better precision, control, and performance when utilized to any trade or system. IoT systems have been utilized across different sectors via their distinctive flexibility and adaptability to any setting. These smart devices improve data compilation computerization, processes, and more via smart devices and powerful enabling tech.

These smart devices are used for analyzing network traffic data, telemetry data (sensor data) derived from healthcare smart devices utilized to monitor an individual's health using embedded sensors and actuators. These embedded sensors and actuators are resident inside IoT hardware devices such as IoT sensor, heart sensor, blood pressure sensor, smart watches and glasses etc and have network connectivity such as GSM (Global System for mobile communication), GPRS (General Packet Radio Service), 3G (Third Generation of Wireless Mobile Telecommunications), 4G LTE (Fourth generation of Data Technology for Cellular Network, Long Term Evolution.


Figure 1: Pictorial representation of IoT devices such as USB IoT Sensor, Smart Watches and Glasses

In this new era, the usage of IoT would bring about tremendous change to the business model for some businesses such as those related to finance, transportation, manufacturing and healthcare respectively.
In [16], it was reported that the appearance of the IoT has accommodated computing devices to connect to each other directly and exchange data amongst themselves. This is vital for the following reasons:

(a). Improvement in sensor and connectivity technologies has permitted smart devices and objects to gather, document and evaluate information that was not easy to get to before. From healthcare point of view, this literally means having the capability to retrieve information concerning patient's health condition that can be utilized in taking preventive measures, allow for quick analysis of severe complications and encourage perceptive knowledge of how an administered treatment is helping to advance a patient's health condition.

(b). The capability of smart devices to assemble facts on their own hereby obliterating the restrictions of manually entered information automatically, retrieving details medical personnel needs at a particular period and format they require of it. This automated system alleviates the threat of mistakes. Less error can mean amplified competence, cost-effective and enhancements in value wherever sector IoT is applied. However, the application of IoT in healthcare is of great interest, where errors committed by humans can make a big distinction between the dead and the living.

### 1.6.1 IoT Application in Healthcare Monitoring

In [16], it was reported that IoT plays a major function in the development of vast healthcare apps, from handling unending ailments at one end of the scale to averting infection at the other. However, here are some instances of how the application of IoT is already playing out and bringing about progress in these areas:

i. Clinical care: Patients whose health condition requires utmost medical attention can be continually monitored via non-insidious and IoT-powered monitoring. However, IoT-powered solution utilizes sensors to gather ample information about patients' vital signs and employs gateways, large storage devices to evaluate and amass sensor generated data and then transmit the analyzed data through wireless connection to medical personnel for further examination and evaluation. This eliminates the method of manual health monitoring of patients' vital signs by health personnel at intervals; rather it provides an uninterrupted computerized flow of data. In this fashion, it concurrently upgrades the value of care through steady attention and minimizes the cost implication of care by expunging the necessity for medical personnel to keenly involve in the compilation and evaluation of data.

ii. Remote monitoring: Lack of proper patient health monitoring has become an issue due to the fact that patients don't have access to valuable health monitoring which is prevalent in Sub-Sahara Africa where some have met with disabilities and eventually death. However, the use of diminutive potent seamless wireless solutions linked via IoT has paved way for continuous monitoring of these patients in real-time. Furthermore, these solutions can be employed to capture data relating to patient health condition from a range of sensors, apply intricate algorithms to evaluate the captured data and then making it available via wireless connectivity to health experts who can formulate suitable recommendations where necessary. This type of monitoring is otherwise remote patient monitoring.

Remote Patient Monitoring (RPM) is a tech that permits monitoring of patients far from the conservative medical scenery, for instance (a patient's home), which might amplify direct contact

to care and lessen the expenditure of healthcare delivery. The application of IoT technology in the area of patient health monitoring is an example of remote patient monitoring.

In this paper, we intend to propose a Patient Healthcare Monitoring System architecture using IoT which will curb the issues surrounding manual method of patient health monitoring in Nigeria.

## 2. Proposed System Architecture

The architecture of the proposed model contains four phases; they are Data Compilation Phase, Data Dissemination Phase, Data Employment Phase and Security Phase respectively. A Wireless Body Area Network (WBAN) will be set up to gather essential data from the patient and consists of sensors or wearables. The parameter used to measure patients vital signs differ. Consequently, each health parameter will be sensed by different IoT smart sensor or an IoT smart wearable device connected to the patient. With the use of smart sensors, temperature, blood pressure and heart rate are monitored in real-time and data gotten from the smart sensors are fed to the IoT server via the internet for analysis.

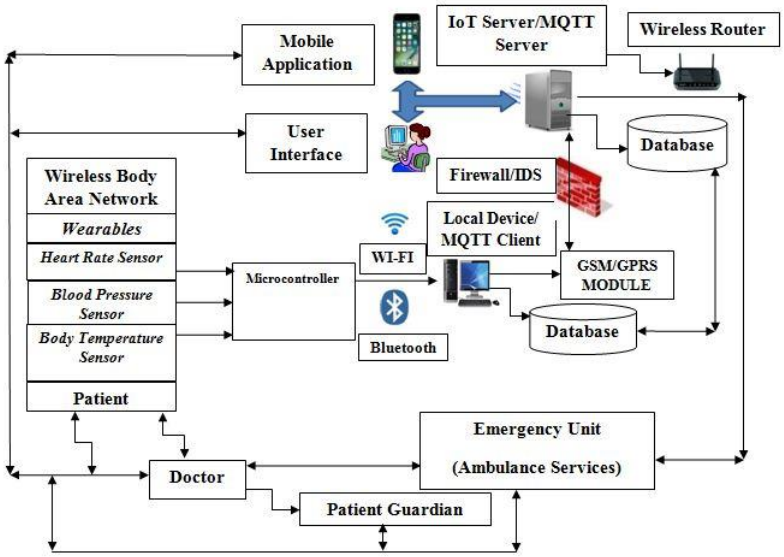


Figure 2: Proposed System Architecture for IoT Based System for Patient Health Monitoring

The transmission devices utilized in the data dissemination phases are Wi-Fi, Bluetooth and internet enabled devices. All sensed data amassed from the IoT devices will be transmitted to the local device/MQTT client that has an application to check the intensity levels of each parameter, with the output sent to the IoT Server via the GSM/GPRS module embedded in the mobile device or the GSM/GPRS modem connected to the computer system. The average of normal body temperature for the human being is 98.6°Farenheint (37°Celcius) which will be measured by the temperature sensor with its output transmitted to the local device/MQTT client via wireless connectivity.

The local device/MQTT client (Messaging Queuing Telemetry Transport client) is connected to the internet via GSM/GPRS module for the transfer of analyzed sensed data via an MQTT enabled App with encrypted port number 8883; the use of TSL (Transport Security Layer) protocol is for a secure communication channel and encryption of analyzed sensed data to the IoT Server/MQTT Server which can be accessed by the Emergency Unit of the hospital, medical doctor to make necessary recommendations. The IoT Server database will update as data arrives from MQTT client.

The IoT Server will be connected to a wireless router with internet connection, and also has MQTT and TSL protocols configured on it for easy machine to machine communication and encryption of data to be transferred privately and securely between local device/MQTT client and the IoT Server. Hence, this makes the IoT Server an MQTT Server.

The wireless router will have NAT (Network Address Translation) configured on it, enabling the IoT Server to have 2 IP addresses, one IP address which will be access to the IoT Server locally within a LAN (Local Area Network) setup within the hospital which is called Inside Local Address and the second IP address which will allows access to the IoT server remotely via mobile/PC (Personal Computer) over the internet called the Inside Global Address.

However, doctors and patients can view details of information sent to the IoT Server using the mobile applet or through the web. The mobile applet can be accessed by medical personnel of the Emergency unit of the hospital via their Access Id and secret code. The medical personnel can view all the details associated with the patients vital signs like and heart rate, body temperature and blood pressure. If patients or patients' guardian want to access the details of the patient on the IoT Server, they have to use the Patient Identification Number (PIN)/Registration number to login and view the details via mobile application and user interface (PC). The PIN uniquely identifies a patient's record on the IoT Server database. The doctor can contact the patient directly via IoT Server to make recommendations based on data retrieved from the IoT Server database.

The usage of information retrieved from the IoT Server by the medical personnel, doctors, patients and patients' guardian via Mobile Application or the web forms the utilization phase of the model. All health parameters can be viewed through the mobile application anywhere anytime provided there is internet connection available. Doctors can even create awareness about diseases and their symptoms through the mobile application. The mobile application is designed for the benefit of all users of the system.

The Firewall, IDS, TSL protocol and use of username and password that is employed between the local device and IoT Server forms the security phase of this model that adds additional security and confidentiality of patient's data transferred within the model.

## 3. Phases of Proposed System Architecture

The Proposed Model has four phases as earlier stated and is discussed as follows:

**3.1 Data Compilation Phase:** The first phase is the data compilation phase. This phase contains the following:

(a) Wireless Body Area Network: It consists of sensors utilize to monitor vital signs such as heart rate, body temperature and blood pressure and wearables which are attached to or worn by the patient to sense the actual state of condition (Sensed data); the patient is at a particular point in time.

(b) Microcontroller: Microcontroller is a miniature computing device on a solo integrated circuit containing hardwares such as memory, processor core and programmable input/output peripherals.PIC defined as (Programmable Interface Microcontroller) is used here to perform the various modules. It has ADC (Analog to Digital Converter) on board which converts sensed data from analog to digital readable format and vice versa. It has I/O ports which allow it to establish connection with other peripherals. E.g. Keyboard, Monitor, PCs (Personal Computer).

(c) Local Device: A device (Personal Computer, Mobile Device) that has software to check the threshold levels of the health parameters received via Local Area Network (LAN like Bluetooth/Wi-Fi) from the sensors attached to the patients. It has a relatively small database. It has MQTT (Message Queuing and Telemetry Transport Protocol) enabled App installed and configured which is an IoT connectivity protocol that allows easy M2M (machine-to-machine) communication between itself, and other devices and for easy transfer of the analyzed sensed data and also TSL protocol for encryption of analyzed sensed data to be sent to the IoT Server via the internet.

(d) IoT Server: A central computer at specific location with large storage capacity or a Network Access Storage (NAS) attached to it, which can be accessed locally within a LAN and remotely via internet (Wide Area Network).

It is connected to wireless router with NAT (Network Address Translation) configured on it. It has MQTT (Message Queuing and Telemetry Transport Protocol) Server enabled App installed and configured which allows easy M2M (machine-to-machine) communication between itself and other devices and the use of TSL (Transport Security Layer) protocol for encryption of data and secure communication channel for transfer of data between IoT server and all clients.

(e) Database: The database stores sensed data captured from each sensor as well as sensed data history. It also provides data storage for daily sensed data records. A digital computer will be used to store all the data.

**3.2 Data Dissemination Phase:** This phase contains the use of the IoT connectivity technology for dissemination of sensed data between the sensors, microcontroller, local device, IoT server and protocols between networking devices.

(a) Bluetooth: Bluetooth is a standard LAN technology used in transmission of sensed data from patient to Local device where threshold check is done and results stored in the database of the local system.

(b) Wireless Fidelity (WI-FI): Wi-Fi is an acronym for Wireless Fidelity. Wi-Fi relies on the IEEE 802.11 family of standards and is mainly a local area networking (LAN) technology also used to transfer sensed data from patient to Local device where intensity check is done.

(c) GSM/GPRS Module: it is a chip utilized to launch interaction between a computing device and a GSM (Global System for Mobile Communications)/GPRS (General Packet Radio Service) network system. It is an embedded piece of hardware that is incorporated within a computing device. A GSM/GPRS modem is a class of wireless modem, designed for interaction which as serves as an external device. Modems need a SIM (Subscriber Identity Module) card to activate communication with the network. GPRS is a mobile data service on the 2G (Second Generation) and 3G (Third Generation) cellular communication network system. Analyzed sensed data are sent to the IoT server through the internet using the GSM/GPRS module embedded in a mobile device or a GSM/GPRS modem connected to a computer system.

(d) Wireless Router: is a network device that allows communication between two networks. It determines the best path through the network and contains configuration files that control network traffic. Generally, it has two connections types namely: WAN Connection (connection to ISP (Internet Service Provider)), LAN Connection. The IoT Server is connected to this device with NAT (Network Address Translation) configured on this device.

**3.3 Data Employment Phase:** The third phase involves the use of sensed data collected from patient, communicated via LAN (Bluetooth/Wi-Fi) and Internet which is been accessed and utilized by the Emergency unit, medical personnel (Doctor and other Health Personnel) to make recommendation based on data received from the IoT Server Database and likewise patient's guardian who wish to access patients health status. It can be accessed through Mobile and Personal Computer (User Interface).

(a) Mobile Applet: is an app developed by an app developer which allows users to use an application developed via small handheld devices such as mobile phones, smartphones, PDAs (Personal Digital Assistant), tablets etc. Mobile apps can be preloaded on the handheld computing device as well as can be downloaded by user from app stores on the internet.

(b) User Interface: is a section of an interactive computer system that communes with the user. The user interface is any segment within the system that is visible and interactive with the user.

**3.4 Security Phase:** The last phase involves the use of firewall, IDS (Intrusion Detection System) to stand as a layer of defense to protect the IoT server from malicious attacks from within and outside because data confidentiality between patients and doctor is very important.

The use of cryptographic protocol such as TSL (Transport Security Layer) is employed in the MQTT enabled App to encrypt messages between the patient and IoT server for data confidentiality and offer a secured communication channel amid the client and IoT server to prevents attacks such as eavesdropping on data sent between the local device and the IoT server which can be perpetrated by hackers or any other person if there is no additional layer of security.

The use of username and password by MQTT clients is deployed before IoT server/broker can been accessed via Mobile App and User Interface thus, preventing unauthorized access to the IoT Server.

(a) Firewall: A firewall serves as a fence that protects information flow and prevents intrusions. Firewall security policies that states which network traffic has authorization to go through the network are also created.

(b) IDS: An Intrusion Detection System (IDS) is a software or hardware or a combination of both that monitors, detects and generates an alert against malicious activity on a host or a network of hosts.

(c) Transport Security Layer Protocol (TLS): It is cryptographic protocol that works with Messaging Queuing and Telemetry Transport Protocol (MQTT) to protect connection between client and server. It uses the handshake mechanism to negotiate various conditions to be met before creating a secure connection between client and the server. On completion of the handshake mechanism, a ciphered communication between client and server is set up so as to thwart advanced persistent threat from eavesdropping any part of the communication. The port number 8883 is exclusively reserved for MQTT connection over TLS, while the port number 1883 is for insecure connection over TLS.

(d) Authentication and Authorization: It requires the use of username and password to access to the IoT server/broker via an MQTT client app. The IoT server authorizes access to itself when username and password of MQTT client has been verified and certified correct.

## 4. Conclusion

Quick access to data about a patient's health and processing this data for required information to aid necessary actions can contribute to successfully treating the patient. In this paper, we have seen that a patient's health can be monitored by means of Internet of Things (IoT). IoT enables the doctors and medical personnel remotely monitor their patients' health even outside their consulting hours hence with data gotten from sensors attached to patients, the medical personnel can timely alert patients and/or their relatives before an emergency occurs. This may go a long way to help arrest cases of sudden attacks, disabilities and death.

From this study, it is discovered that the IoT technology if implemented in the Nigeria health sector to help monitor patients health will provide personalized and optimized services, reduce mortality rate, promote a better life style, help save productive citizens and eventually lead to development of the Nigerians nation. This is envisaged as a way forward to proper patient health monitoring in Nigeria.

This proposed system architecture can be deployed in Nigeria, particularly in a metropolis where emergency and ambulance service units run on a 24/7 basis like LASAMBUS (Lagos State Ambulance Services), LASEMS (Lagos State Emergency Medical Services etc) and are stationed at different locations within the metropolis which can aid quick convey of patients to the hospital in case or before an emergency occurs.

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