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**Research Thesis Title:**

# IOT-BASED SYSTEM TO MONITOR HEALTH CONDITIONS OF ELDERY PEOPLE IN RWANDA

***A dissertation submitted in partial fulfillment of the requirements for the award of masters of science degree in internet of things: wireless intelligent sensor network***

Submitted By:

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**December, 2022**

**DECLARATION**

I, Theodosie UWIZEYIMANA, Master ‘student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented before anywhere in the world.

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Date: ……/……/……

**BONAFIDE CERTIFICATE**

This is to certify that this submitted Research Thesis work report is a record of the original work done by Theodosie UWIZEYIMANA (**Ref. Nu:221000150**), MSc. IoT-WISNET Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things, the Academic year 2020/2021.

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## ABSTRACT

The rapid increase in number of the old adults in developed countries has raised concerns about their well-being and increased needs for healthcare services. Elderly people faces different old-age related diseases such as Cancer, Alzheimer, cardiovascular, blood pressure and sugar level problems where some of such diseases transform into chronic diseases. However, without assistance, aged persons are helpless. Even informing someone about their health issues is challenge for them. In developing countries new technologies, including internet of things, are being used to monitor old adults' health and activities, thus enable them to live safe and independently at home as they age. This study aimed at designing and prototype a system intended to help improve health of elderly people in Sub-Saharan Africa. This can be achieved by providing a relatively easy way to monitor the health of elderly people remotely and provide vital signs information of elderly people periodically with automatic alerts in case of emergency issue and tracking the location of elderly people. Therefore architecture for context awareness and IoT-based system is proposed to improve health monitoring of elderly people in Africa and thus improve the quality of life of elderly people**.** The system use heart beat sensor, Temperature sensor and GPS Module to collect data with Arduino Uno as Microcontroller. The collected data is send to the cloud using GSM Module. The cloud data is stored, processed, analyzed and then sends to the caregiver and Doctor. The use of this system will help elderly people to get real time health status and medicine anywhere by ensuring a timely response in case of emergency, thus improve their quality of live. Lastly the system will help caregivers and doctors to monitor elderly people remotely thus improve health worker productivity, reduce consultation time and overall healthcare cost.

***Keywords—Internet of Things, Health Monitoring, GSM, Cloud, Elderly People Monitoring,***

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## LIST OF SYMBOLS AND ACRONYMS

**GPRS** : General Packet Radio Service

**GPS** : Global Position System

**GSM** : Global System for Mobile Communication

**IoT** : Internet of Things

**MSQL**: Structured Query Language

**OLED** : Organic Light Emitting Diode

**PCB** : Printed Circuit Board

**PHP** : Hypertext Preprocessor

**SMS** : Short Message Service

# CHAPTER ONE: INTRODUCTION

## 1.1 General Introduction

As the world population grows, there are also the increasing of the older population, and the number of patients who require health monitoring increase [1] According to a report released by the United Nations, the proportion of persons aged 60 years and older, compared to the total population, is expected to double between 2007 and 2050, and reach 2 billion by 2050 [2].

Through, analysis of literatures show that Sub-Saharan Africa carries a high disease burden and the elderly population in this region is set to increase from 36.6 million to 141 million by 2050 and health monitoring of elderly people is still challenging in this region. [3]

In the US, the mortality rate is over 770,000 per year. This includes patients who suffer sentinel events associated with; incorrect medication, dosage inaccuracies, contraindications or critical delays in interventions resulting in hospitalization. [4] The aggregated cost of these events across the US is between $1.5 billion and $5 billion annually [5]. Therefore, health monitoring systems can play a significant role in reducing hospitalization, burden of medical staff, consultation time, waiting lists and overall health care costs in developed and developing countries [4]. The application of modern technologies to monitor health of elderly people is very low in Sub- Saharan Africa [6]. The internet of things (IoT) enables device interconnection where physical and virtual things are connected and centralized data [7]. And also IoT has proven significant benefits in healthcare sector, especially now that the circumstances have changed due to COVID 19 pandemic, and social distance is encouraged worldwide [8]. Remote Monitoring Systems involve using various sensors within the medical equipment to continuously check different patient's parameters and have proved effective [8]. The topic of IoT and elderly health monitoring still have the potential for further exploitation to improve the current systems that have gaps and limitations. They are expensive, not easily accessible by people in developing countries; they do not send the health information to the users, and most lack alert notification and tracking capabilities.

Therefore, this study reviewed the existing systems healthcare facilities for elderly people in Sub-Saharan Africa, proposes an architecture for integrating IoT into existing system for Sub-Saharan Africa healthcare facilities and designs a prototype for such a system.

Data on existing solutions were collected through observation and reading literature. The proposed architecture and system will drastically enhance the integration of IoT into elderly people health monitoring, resulting in more context-aware solutions, improved service delivery consequently improve the life of elderly people and overall cost of hospitalization.

The system employs sensors, the body temperature sensor, heart beat sensor and GPS Module. The data is stored, processed, analyzed and sent to the doctor and caregiver from the cloud in real-time and take decision accordingly.

The system also provides an alert notification in case of abnomality or emergency issues and provides elderly people health information periodically. The system use open source technologies to ensure reduced cost. Arduino for hardware development is used and Arduino IDE, is also used the online dashboard for data visualization, monitoring and storage

**1.2 Background and Motivation**

The Fourth Rwanda Population and Housing Census established that there were 511,738 older persons (60 years old and above) living in Rwanda out of a total population of 10,515,973 inhabitants. Older Persons represented 4.9% of the total resident population [9]. Those people faces with different challenges

i) Access to healthcare services: For the elderly, especially that with-long term illnesses, to access the healthcare services, to coordinate the administration and other form of treatment is not easy for them. They are struggling looking those services, so they need someone to help them in order to find those services [6].

ii) Finding the right care provision: Most of elderly people require additional care .This care can be provided by their family members, but this can cause a lot of stress on the caregiver in terms of managing this with work and other family responsibilities. These caregivers need to be given the training, resources and emotional support necessary to help them to deliver the best care for their loved ones and themselves. In some cases, it is more appropriate for a professional caregiver to be employed on regular basis [6].

iii) Difficulty with everyday task and mobility: Elderly people need more support through products in their everyday activities in order to help them to live independent at their home and also to ensure that they have the opportunity to grow as individuals [6].

iv) Long waiting times: Elderly people, especially those struggling with long term conditions spend whole day when they visit health center to see health professional because there is a long queue of patients who look for medicaments [6].

According to the analysis of literature shows that there is lack of use modern technologies to monitor the health of elderly people Sub-Saharan Africa especially in Rwanda, elderly people with long term illness visit the health center facilities in daily basis to meet with medical professional and also they are struggling because there is a long queue of patient who look for treatment and medicaments. This shows that they need an establishment of a strong healthcare system to monitor health conditions of elderly people such as temperature, heart beat and also to track their location. That's why we feel motivated to undertake the research thesis by focusing on big challenge faced by elderly people in Rwanda. Where an IoT system to monitor health of elderly People is proposed for the purpose of monitoring the elderly people health status and to track their location in order to help them live independent and safe and also to improve their quality of life.

In such way there is increasing of number of hospitalization, consultation time, burden of medical staff and overall healthcare costs. In order to overcome those problems, a proper and efficient system is proposed to monitor various health status of elderly people and to track their location.

**1.3 Problem Statement**

In Rwanda elderly people are increasing and they face many challenges such as difficulty of everyday tasks and mobility, access to healthcare services, long waiting time when they visit health center to see health professional and finding the right care provision. Referring to the reports of the National Institute of Statistics of Rwanda, there were 511,738 older persons (60 years old and above) out of a total population of 10,515,973 inhabitants, these older persons represented 4.9% of the total resident population. [10]

When it comes to health issues affecting the elderly people, non communicable or chronic diseases such as heart disease, cancer, and diabetes are becoming more frequent [11]. Their healthcare system is more expensive and in most of time they are need of caregivers or doctors to help them in everyday activities [6]. They use traditional method to monitor the elderly people health status; when there is anomaly in the health state of elderly people, there is no way to notify caregivers or doctors [6].

In additional they do not have real time monitoring system to monitor elderly people health status. This shows that they need an establishment of a strong healthcare system to monitor health

conditions of elderly people such as temperature, heart beat and also to track their location. The system that can be used to help caregivers or doctors remotely monitor the health of elderly people and send real time data using IoT technology.

## 1.4 Study Objectives

### 1.4.1 General Objective

The main objective of this system is to design and prototype an IoT based remote health monitoring system for elderly people, tracking their location and send real time data using IoT.

### 1.4.2 Specific Objectives

- To review the existing literature on how elderly people are monitored
- To design an IoT system that will notify the doctor and caregiver about health status of elderly people
- To develop IoT health monitoring system using parameters like temperature, heart beat and tracks the location of elderly people.
- To propose an architecture for integration of IoT with existing elderly monitoring system.

## 1.5 Hypotheses

The hypotheses for the study were: 1) it is possible to use IoT based technologies to develop a real-time elderly people health monitoring system. 2) The IoT System to monitor health of elderly people in Rwanda will come up to solve the challenges faced of not getting real time health status of elderly people. This Prototype will be used to help caregivers or doctors remotely monitor the health of elderly people and send real time data using IoT technology

## 1.6 Scope of the Study

The thesis was focused on monitoring the health conditions of elderly people in Rwanda by monitoring parameters such as temperature, heart rate, and tracking their location. Data was collected from elderly people in different location. Within the implementation of a prototype, the solution will eliminate the gaps existing in the literature during the health monitoring of elderly people.

## 1.7 Significance of the study

The thesis aim is to design and implement an IoT system to monitor health conditions of elderly people in Sub-Saharan Africa especially in Rwanda; this is help developing nation governments in increasing health workers productivity, reducing consultation time and related healthcare cost.

If implemented, the system will help elderly people to get health status on real time and medicines anywhere; thus improve their quality of live, Helping Caregivers and Doctors to monitor elderly people remotely. The proposed architecture will also act as guide for use in integration of IoT systems into the existing solutions.

### 1.8 Organization of the study

The rest of the study is organized as follows:

Chapter 1: Presents introduction, which includes the background of the study, problem statement, general objective, specific objectives, hypothesis, scope, significance and organization of the study.

Chapter 2: Presents a review of related literature.

Chapter 3: Outlines the methodology applied in the study.

Chapter 4: Presents the System design, Results and Discussion

Chapter 5: Presents Conclusion and Recommendations.

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Introduction

This Section reviews IoT healthcare related literature, Remote health Monitoring technologies, how it is currently done in remote communities, the promising technologies for elderly care .It also discusses the existing solutions and existing open prototypes and their limitations .Previous works are presented and describes similarities technologies and contrasting features are discussed.

### 2.2 IoT in Health Care

Nowadays many researchers are very interested with real time solutions, looking for ways to help different people, such as children, the elderly and people with various disabilities to get better services. A remote e-healthcare system with the help of medical equipment, which help patients used by these healthcare providers, where they could respond to the patient who asked for help

The web application was developed by Ray et al, so that patients who are at long distance from their clinics or who are remotely, they could use their system known as e-Health telemedicine, which helps those who want to monitor their pulse oximeter, Electrocardiogram (ECG), Blood pressure and body temperature where the system will help the doctors and patients to communicate in a way remotely and it seems to help users of this system [12].

As an aspect of IoT, Ubiquity allows devices with sensors and microcontrollers to interact and communicate with one another, healthcare sector like many others, continues to gain from IoT concept. [13]For instance, the patient monitoring system in hospitals may interact, act and upload data to the cloud. This has brought so many benefits to the health care sector, in terms of improved patients health, increased health worker's productivity, and reduced overall health care operational cost as an IoT enable remote monitoring [13].

The development of new technologies, such as 5G, AI, and Big Data, will favorably affect the expansion of IoT in the healthcare industry. They can offer very fast speeds, mobility, and real-time decisions from data analysis using AI algorithms, minimizing errors and improving treatment outcomes [13]. It is expected that IoT will transform healthcare [14].

### 2.3 Review on Remote health monitoring system of patient people

Remote monitoring in healthcare is a method of using technology to monitor, and caring patient anywhere at any time in non-Clinical environment such as in the home to improve the efficiency

engaged in healthcare services [15] to facilitate the treatment in real-time and safe the life of critical cases like when the health status of the patient reaches at risk [16]

**2.4 Health monitoring for elderly in developing nations**

In most developing nations especially in rural communities, health monitoring for elderly is done following traditional approach; [17]

In South Africa, the majority of older adults utilize primary healthcare facilities for their health needs, while a small number of pensioners also access services from private general practitioners or traditional healers [17].

Patients in rural area visit medical centers .Basic medical data is sent to eHealth platform ((Network server) at secondary referral hospital where specialists analyze information, finally diagnostic information is sent to healthcare [17]

**2.5 The promising of different technologies for elderly care**

There are number of promising technologies to support elderly people in developed countries, here we discuss some of them:

i) Telemedicine: Aims to benefits patients who live in isolate communities by giving them a means to access healthcare information from doctors or specialists with out to visit them in person. Telemedicine is about the delivery of medical care over distance and consultations by phone or video conferences between patient and doctor. In developing countries like Pakistan, telemedicine is used to handle health issue. In Greece also, telemedicine is used by patients located in remote island location [18].

ii) Telehealth: The remote collection of patient data such as blood pressure. In US, implementation of Telehealth can improve care of Medicare beneficiaries [19].

iii) Telecare: The provision of remote care with the help of environmental sensors to detect for example falls or fire. A local project in Poland aims to improve quality and safety at home for older people by providing them with telecare [19].

iv) Telecoaching: A method focusing on behavioral change to aid recovery. It can delivered by different digital tools such as a computer and a smart phone [19].

v) Active and Assistive Living: Deploys ICT in the form of assistive technologies supporting elderly in their daily lives. They can be defined as home based systems or devices that support diverse activities of old adults, and allow an individual to perform

task they would otherwise be unable to do or increases the ease and safety with which the task can be performed [19].

vi) Robotic technology: Is expected to help older people to gain independence and is emerging an approach to assist old adults with for example robotic wheel chairs, shower chairs. Robotic technologies can also be applied indirectly for older people through the provision of support to caregivers [19].

### 2.6 Existing open prototypes to monitor elderly people

This part outlines the state- of- the art frameworks used in elderly people monitoring based on IoT. A Significant of IoT based to monitor elderly people exists. Many of these studies are carried out in developed countries and are costly do not favour population in developing countries [20] [21]

For example study [22], work on building an IoT-Based Health Monitoring System for Active and Assisted Living, the proposed architecture collects the data and send it to the cloud where it is processed and analyzed, they use Bluetooth technology to send those collected data to the cloud and also iBeacon indoor localization technology is used to locate the patient .In this paper there is a of lack of direct monitoring from medical staff or caregiver which limits assistance in case of emergency**.**

Kosanovic & Al, They implemented of remote Wellbeing and health monitoring of the elderly people by using off the shelf hardware (smart watch and mobile phone), in the paper authors illustrate such a system by using two off- the shelf smart watches for activity recognition. However they do not propose a system that can at the same time be used for overall monitoring the person health state. In this review the data latency is the main issue in case of emergency. [23]

Mohammed Al-khafajiy&Thar Baker proposed Cloud-based Smart Home Environment (CoSHE) for Home Healthcare. They develop Cloud-Based Smart Home Environment for home healthcare, which collects physiological signals through non-invasive wearable sensors and provides contextual information in terms of daily activities and location in the home. The collected data are sent to the cloud via Home Gateway.

The system enables healthcare professionals to study daily activities, behavioral changes and monitor rehabilitation and recovery process. In this study there is lack of alert notification to caregiver or professional when the elderly people face potential emergency situations [24]

In [25], a system proposed to monitor body temperature using wearable devices with IoT integrated the real time warning and stored data analysis. It is an advanced technology abnormal behavior

detection based on video was proposed a novel clustering to gather patient data from outside the clinical environment and caring for patient from a far with a long distance from health facilities, this method had been used by the medical staff to monitor the health parameters of patient while patient staying at home but the system does not truck the location of patient. A combination of enabling technology such as sensing technology, communication technology and data analysis techniques have the potential capability to report the information about patient's symptoms [25].

### 2.7 Summary

The above studies have contributed to improve health monitoring using IoT but have restrictions as majority of them were carried out on population from developed notions and therefore they are expensive, not easily accessible by people in developing countries; they do not send the health information to the users, and most lack alert notification and tracking capabilities [25]. The existing system that is currently in use indicates that there is still problem of monitoring health of elderly people for better providing them good services by getting real time information about their health status anywhere at any time.

Due to those difficulties or challenges on monitoring health of elderly people, the proposed system will come up with the aim of improving the way of monitoring health conditions of elderly people. The study targeted the elderly people living alone, which are located in different area of locations. In this study we expected to collect data from biological sensors such as heart beat, body temperature and to track the location of elderly people.

### 2.8 Research Contribution

Our research focuses on designing and developing an IoT- based system to monitor health of conditions of elderly people by monitoring parameters such temperature, heart beat and tracking their location.

Referring to the report of National Institute of Statistics of Rwanda, elderly people are increased at rate of 4.9% [9]. Their health is affected by non-communicable or chronic diseases which becomes more frequent [3].

In order to find medicines or other forms of treatment, elderly people visit the health center facilities and they are struggling because of long waiting queue of patients who look for the professional. In case of abnormal in their health, there is no way to notify caregiver or doctor; means there is no real time monitoring system. To overcome those challenges, this thesis research focus on monitoring temperature, heart beat and tracking the location of elderly people. This

solution will improve the life of elderly people as they receive their health status on real time and medicines anywhere, help caregivers or doctors to monitor elderly people remotely, thus will increase health worker productivity, reduce consultation time and related health cost.

## CHAPTER THREE: RESEARCH METHODOLOGY

### 3.1 Research Design and Tools

A mixed research design approach involving both qualitative and quantitative research was used for better understanding the existing elderly health monitoring systems and provide complete evidence for integration of IoT in elderly health monitoring in developing countries. Data was collected from elderly people in Rwanda from different location. Physiological data such as body temperature ($^0$C), heart rate (Pbm) was collected. Observation, documentation analysis guides were used as the main tools for collecting data.

The selection of those tools was guided by nature of the data to be collected, time available as well as by the objectives of the study.

The Observation Method: During the observation, the research data findings were based on seeing the way of monitoring health of elderly people were being done in Rwanda.

Therefore, the research made indicates that: The majority of older adult utilize primary healthcare facility for their health needs, Patient visit medical center to see professional medical, Elderly people with long term illness, to access the healthcare services is challenge, sometimes they spend whole day to see medical professional when they visit health center. They use traditional method to monitor health of elderly people.

### 3.2 Embedded System Design

In this section the embedded system level design is presented; First system architecture is outlined followed by the system design. The system components, system flow chart and Use case diagrams are presented.

#### 3.2.1 System Architecture

Figure 1. Give the system architecture. The main components of the architecture include sensing unit, the microcontroller connect to GSM internet gateway, an open cloud server, a GSM module and user alert unit. The sensing unit is made by temperature sensor, heart beat sensor and the GPS module connected to the microcontroller. These sensors collect data for the different parameters and track elderly people's location. The GSM modem connects on the system then transfers the data to the cloud server for storage, analysis and processing. The processed data is sent to the caregiver and doctor mobile and display on the LCD.

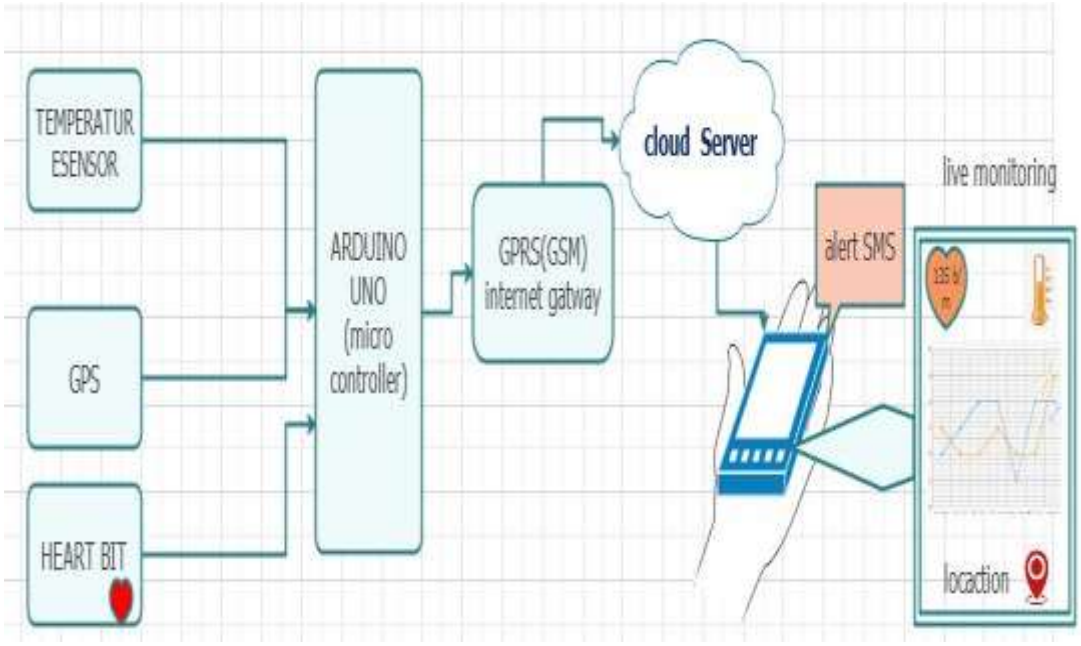



**Figure 1: System Architecture**

### 3.2.2 System Block Diagram

Fig 2 gives the embedded system block diagram showing different system components. Thermistor PTC 1K sensor was used to sense the body temperature,MAX30100 pulse sensor to sense the body pulse and BN-801 GPS sensor for detecting real-time location. The AT mega 328 was selected as microcontroller. The GSM module chosen was a Sim 800L with OLED being used for display.

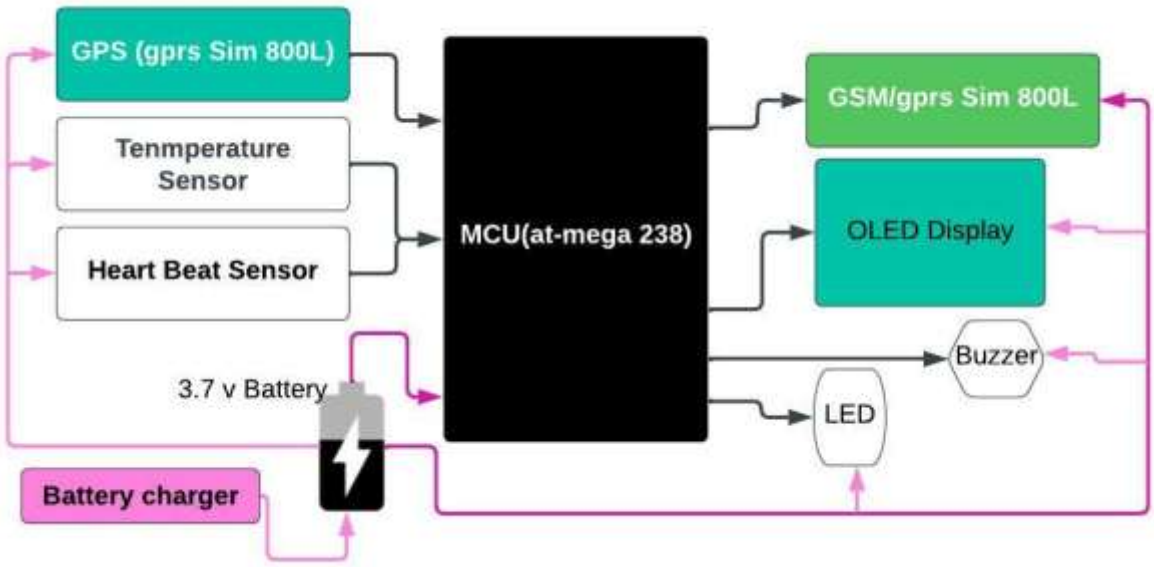


**Figure 2: System Block Diagram**

### 3.3 System Components

The system is made up of both hardware and software components. The components have been grouped in categories based on their functions.

#### 3.3.1 The sensing Module

This is basically the data collection part of the system which is comprised of different sensors that take parameters from elderly people's side and send to the cloud for storage, analysis and processing.

**a) Temperature Sensor**

It is recommended that an old adult over age 65 body temperature should not exceed 37 degree Celsius [26].

The temperature sensor was chosen to measure the body temperature level of elderly people, this is placed on the hand of the user and the reading is taken. When this reading exceeds the threshold value which is 37$^{o}$C the alert is triggered. In this system we use Thermistor PTC 1K because are very sensitive and react to very small changes in temperature, they are stable and powerful, they give quick response and are not expensive as compared to other types of temperature sensors [27].


**Figure 3: Temperature Sensor PTC 1K**

**b) GPS Module**

The Global position system (GPS) is a system that navigates basing on the satellite. It works anywhere at any time at Zero changes. The GPS Module in the system is to enable real time location of elderly people in case of emergency. In this system GPS Module GN-801 is used, with

power specification of DC voltage 3.3V-5V, typical 5V. This GPS is easy to use, ultra-high power performance and low power.

**Figure 4: GPS Module GN-801**

**c) Pulse sensor**

The pulse sensor is a device that monitors the change in volume of the blood vessels occurring when the heart pumps blood. They use the photoelectric pulse wave methods to measure the heart rate [28] This can be either transmission or reflection, as the former emits infrared light from the body surface as it detects changes in blood volume as the heart beats and the later emits infrared lights towards the body as it measures the amount of reflected light using a photo transmitter [28] In this system MAX 30100 PULSE OXIMETER is used.


**Figure 5: MAX30100 Pulse Oximeter**

### 3.3.2 System Control Module

The whole system is controlled by the Arduino UNO microcontroller. Arduino UNO is low cost, open source and easy to use board with A Tmega 328 microcontroller. [29] It has 14 digital input/output pins six which are PWM outputs, 6 analog inputs, and USB connector

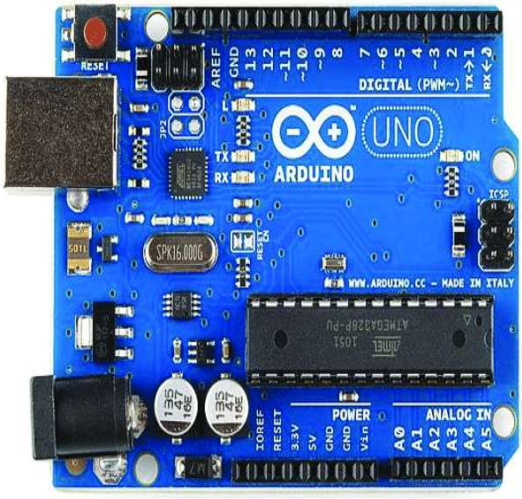



**Figure 6: Arduino Uno At mega microcontroller**

### 3.3.3 Communication module

The collected data from the sensors is sent to a remote database via GSM communication. GSM is an open digital mobile communication technology used widely in IoT applications due to its affordability and simplicity [30]. It transmits voice and data at the 850MHz, 900 MHz, 1800MHz and 1900MHz frequency bands [30]. The GSM modem device is used to communicate over network and it requires SIM card to operate [30]. This system used GSM SIM 800l modem to communicate and send collected data from the sensors to the remote database. The SIM 800l has features like 3.8V-4.2V power input, uses 850, 950, 1800, 1900MHz frequency band and allow receiving and sending SMS as well as mobile calls.

**Figure 7: GSM Module**

### 3.3.4 The Cloud Platform

The cloud platform allows products both software and hardware to co-exist remotely and enables data to be stored, analyzed and processed remotely [31] . The cloud platform used in this system is the IoT mystore.techadopter.rw cloud dashboard. The dashboard that designed for graphical user interface (GUI), it helps the user to enter measurement into the system which was developed

using JavaScript programming language and Hyper-Text Markup Language (HTML5). In this system sensor data was sent using GSM module to the dashboard cloud platform, sent data is visualized and an alert system is sent to the doctor and caregiver via SMS notification in case of emergency need.

In this case when the data from elderly people end exceeds threshold temperature, heart beat values an automatic Msg is sent to the doctor and caregiver to implicate the condition of elderly people.

### 3.4 The system functionality

This part explains the flow both instruction and data in the system and how it functions. It also explained the data flow its function in the system. It presents the processes details of how can be implemented.

#### 3.4.1 System flowchart diagram

A flow chart is the way of displaying the data into the system and describes where the decision takes place. It describes the step by step to monitor health of elderly people using Internet of Things, how to speed up real time information to the caregiver and doctor. The main task of the system is to monitor parameters such as temperature; heart beat and tracks the location of elderly people based on the threshold value state by considering the normal temperature and heart beat of normal person. When the temperature or heart beat values reach the threshold values, a massage notification are sent to the caregiver and doctor for taking decision accordingly.

The figure below indicates an algorithm using flowchart by taking about how IoT system to monitor health of elderly people in this thesis is done. The system functionality continues its tasks of monitoring body temperature, heart and tracking the location of elderly people and notifying the caregiver and doctor in automatic way except if there are technical issues. The system functionality is based on embedded devices, integrated system consists with both software and hardware parts.

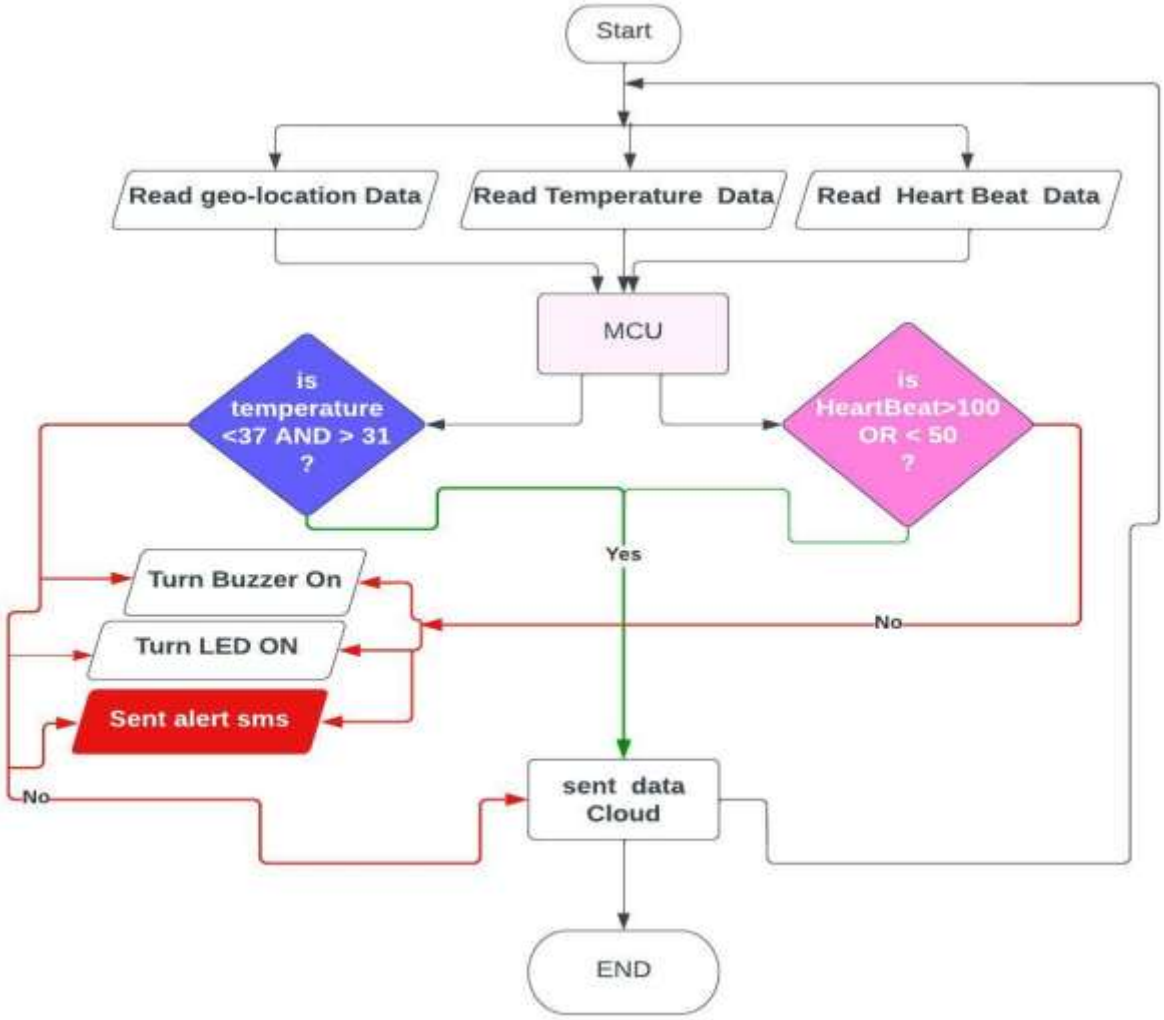



**Figure 8: System Flow chart diagram**

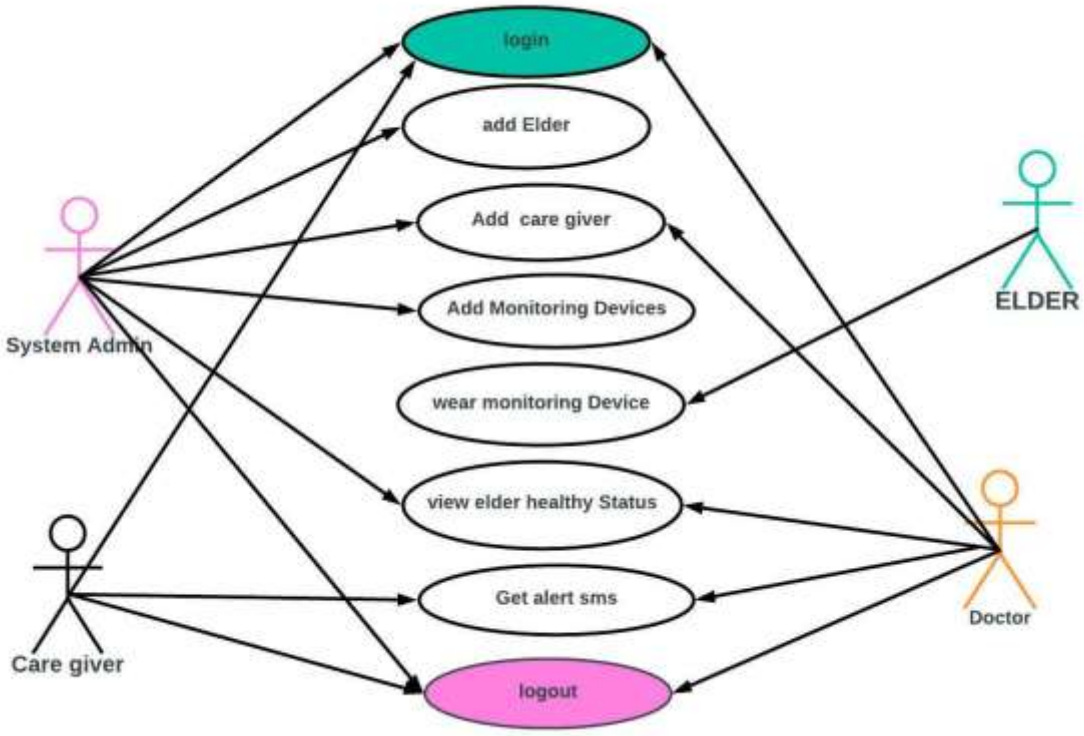



**Figure 9: System Use case diagram**

### 3.5 System Setup

This section describes the setup of the system prototype.

#### 3.5.1 Connection of different components

The different components of the system were connected to the board as follow as shown on the below figure below.

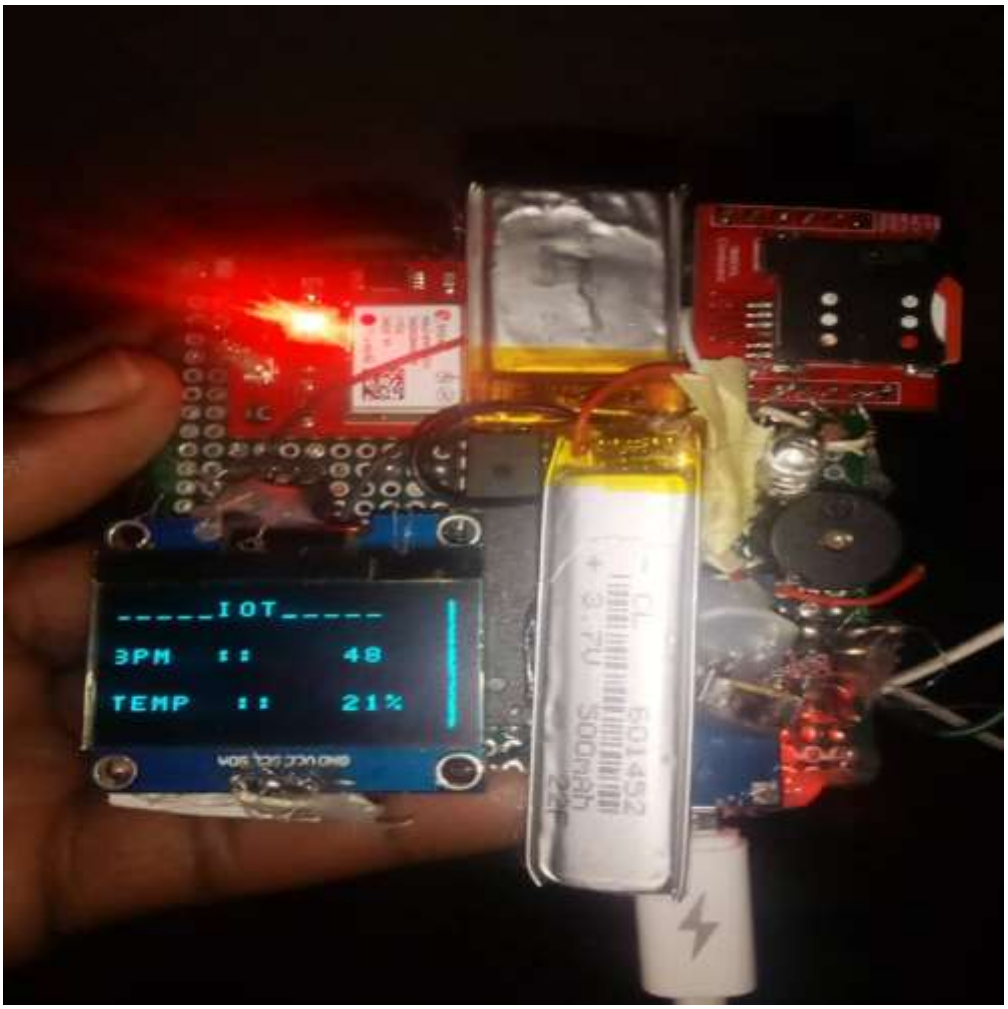



**Figure 10: Protype connectivity and Hardware connectivity on the board**

## CHAPTER FOUR: SYSTEM DESIGN, RESULTS AND DISCUSSION

This section describes step by step the system analysis and the results obtained. The system was designed and working prototype was developed using the different hardware components and data sent to the cloud platform.

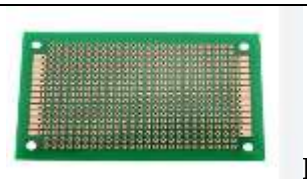
### 4.1 System Design

#### 4.1.1 Hardware Connectivity

The system is a combination of Hardware and Software. The hardware consists of Arduino Uno, temperature sensor, heart beat sensor, GPS sensor, GSM module, Buzzer, LCD. In this section, we emphasize on the functionality of the system by discussing the operations of the sensors, type of parameters to be monitored, the process of gathering data, storage and analysis. Figure 4-1 indicates the major components of an IoT system to monitor health of an elderly people, which includes a sensing unit, a communication unit, and data analysis unit, each of which performs a specific function. The appropriate components like temperature sensor, heart beat sensor and GPS sensor have to be used to collect data, Arduino Uno is used to process the collected data and transfer the processed data to the cloud dashboard for storage and analysis . The processed data is sent to the caregiver and doctor mobile phone in case of abnormal condition, and displayed on LCD.

**Table 1: Hardware Components**

| Components | Descriptions |
|---|---|
|  **PTC1k Thermistor** | This device is Thermistor PTC 1K temperature sensor, it is used to measure body temperature sensor. Have resistance that will increase as their temperature goes up. It is very sensitive and reacts to very small changes in temperature; it is stable and powerful and gives quick response. |
|   **MAX30100** | This module is pulse oximeter and heart rate monitor sensor solution means that it can measure the oxygen level in blood and heart rate. It has an I2C to facilitate communication with the microcontroller and it is faster for data output capability. |

| | |
|---|---|
|  **Buzzer** | Buzzer is like a magnetic sensor, it uses voltage and different frequencies for making a sound or beeper. It makes sound due to applied voltage to the piezoelectric, and this material deforms. |
|  **OLED display** | Organic Light Emitting Diodes (OLED) is a flat light emitting technology, made by placing a series of organic thin films between two conductors. OLEDs are emissive displays that do not require a backlight and so are thinner and more efficient than LCD displays. |
|  **GPS Module** | A Global positioning system for by which anyone can always obtain the position and time information anywhere in the world. It consists of the three segments: Space segment, Control segment and user segment. |
|  **GSM Module** | SIM 800L GSM/GPRS module is a miniature GSM modem, which can be integrated into a great number of IoT projects. You can use this module to accomplish almost anything a normal cell phone can, SMS text message, make or receive phone calls, connecting to internet through GPRS, TCP/IP. |
|  **PCB** | PCB (printed circuit board) is the board used to connect electronic component to one another in a controlled manner. |
|  Atmega328 | At mega 328 microcontroller |

| | |
|---|---|
|  **Jumper wires** | A jumper wire also known as jumper wire, jumper cable or cables is an electrical wire or group of them in a cable with a connector or pin at each end that is used to connect the components of a breadboard or other prototype or test device. |

### 4.1.2 Software requirements

In this thesis different software are used: C++ for hardware development, JavaScript and PHP are used for web server development and lastly MSQL cloud is used for database.

### 4.1.3 System Architecture

The IoT based system to monitor health condition of an elderly people in Rwanda consists of three tiers: tier-1 consists of wireless sensor nodes and control unit, tier-2 is intermediate receiving unit that is responsible for storage, processing and displaying the data, and the third one is concerned with data transmission and alert notification. According to the different activities on the layers, this system is in 5 layered architecture that consists of perception layer, processing layer, transport layer, storage layer and application layer. The elderly monitoring system is made up of sensors that connected to the elderly people and communicate with each other.

### 4.1.4 System design and limitation

Based on different findings in literature review indicates that in the developing countries especially in Sub-Saharan Africa, we are still having the gaps on real time monitoring of the health of elderly people by measuring different parameters like body temperature , heart beat and tracking their location and also to notify the caregiver or doctor about the health status of elderly people in order to take decision accordingly anywhere anytime, and there is a gap of skilled and knowledgeable people in the new technology like Internet of Things(IoT). So that, the goal of designing and implementing an IoT system to monitor health of elderly people helps to overcome those challenges by helping elderly people to get health status on real time and medicines anywhere; thus improve their quality of live, Helping Caregivers and Doctors to monitor elderly people remotely; Reducing consultation time and related healthcare costs.

After developing, testing and verification of the implemented system, the results are shown on dashboard IoT cloud where the results are stored, analyzed and visualized as shown in the figures below.

This figure shows that we have an account in myeleder.techadopter.rw cloud platform and elderly monitoring dashboard was created.

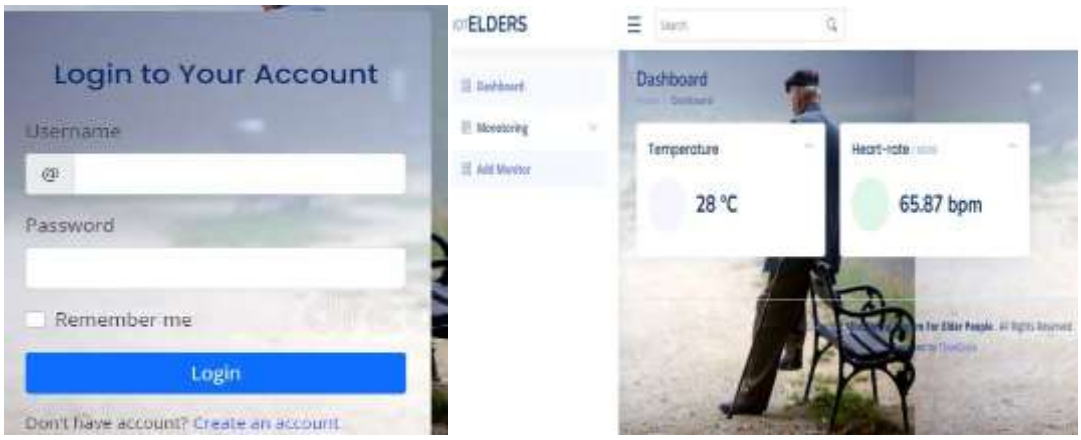



**Figure 11: Account Login and Myelder dashboard created**

### 4.2 Results

This part outlines vital signs results of elderly people collected by the sensor. The system consists of two parts: Hardware and IoT cloud dashboard platform .Both parts are essential for the system, and users can obtain result notification from both**.**

#### 4.2.1 System prototype

To obtain actual results, a system prototype was designed

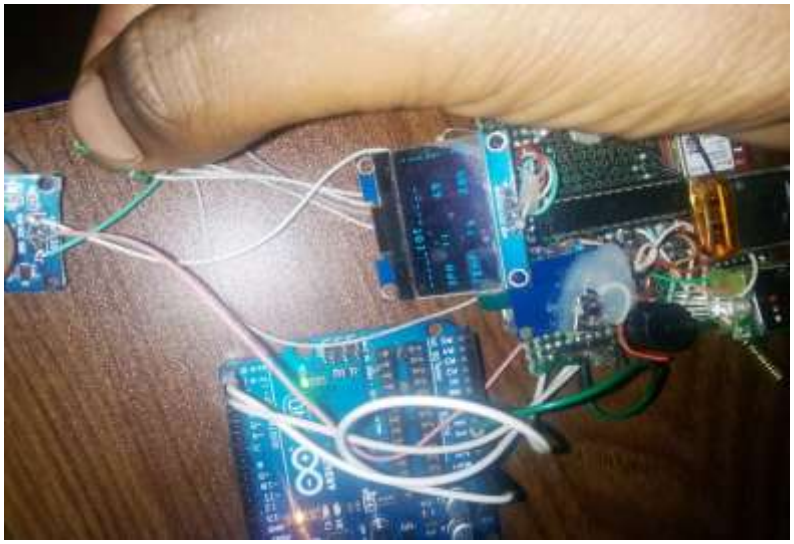


**Figure 12: System prototypes displaying the heart beat and temperature sensor readings**

### 4.2.2 Cloud platform dashboard and visualization

After the system data was collected it was sent via GSM module SIM 800L to the cloud storage. The figure below shows the created cloud platform dashboard.


**Figure 13: Elderly Monitoring System Dashboard**

Figures below show the data entries made over a period of time graph. The graph visualization in dashboard that indicates the variation status of temperature and heart beat in real time.

The above figure shows the temperature variation graph of elderly people over period of time.


**Figure 14: Elderly People Temperature Variation**

The below figure shows the heart beat variation graph of elderly people over period of time.


**Figure 15: Elderly People Heart Beat Variation**

### 4.2.3 Results displayed on LCD

The below figure shows, body temperature sensor data and heart beat data displayed on OLED display in real time.

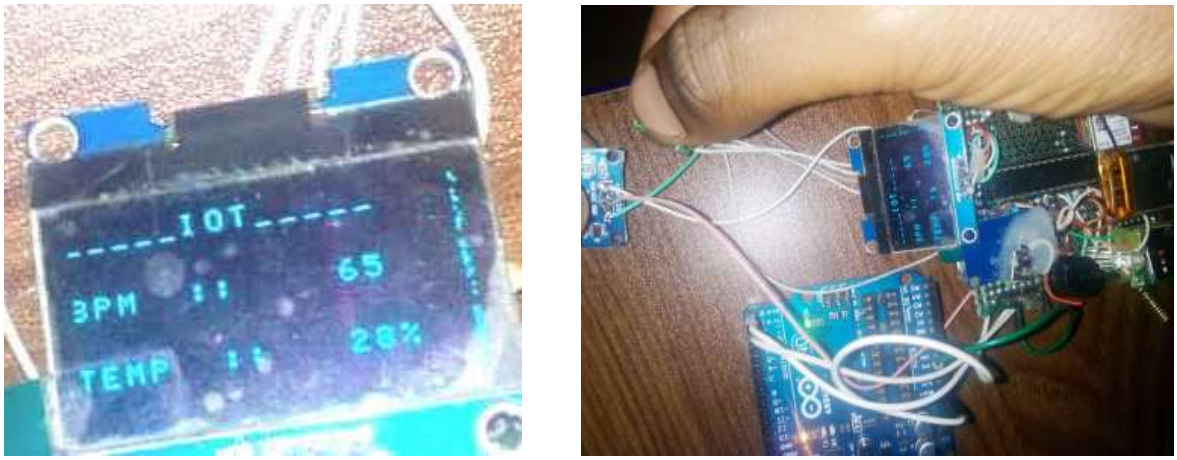
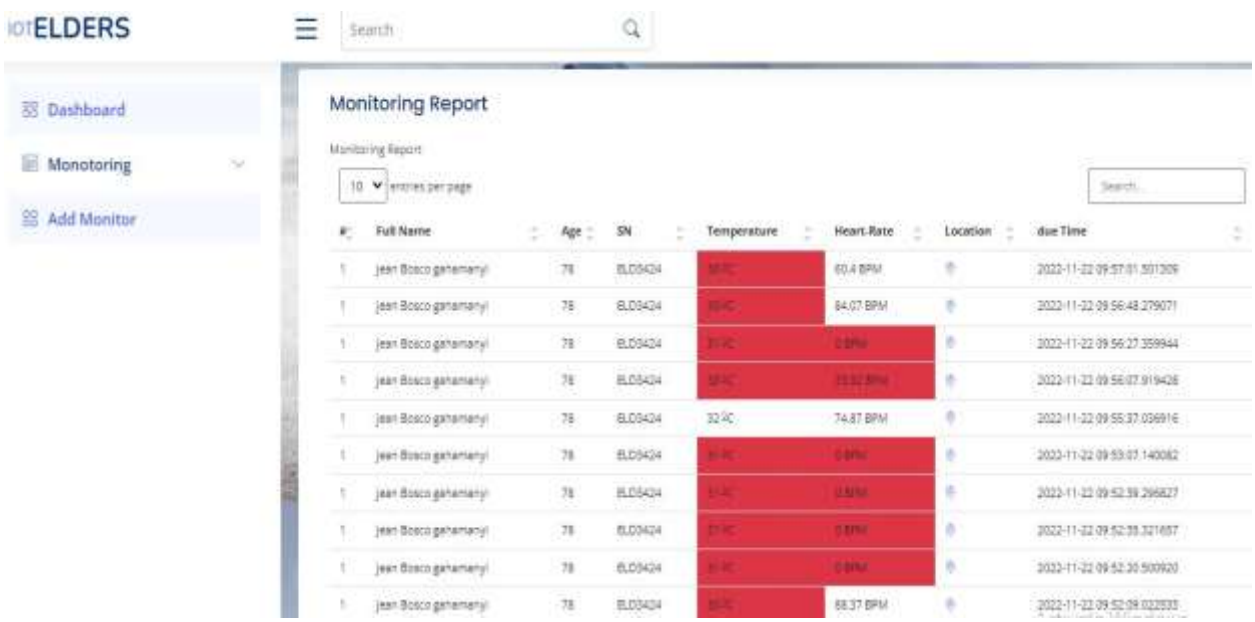



**Figure 16: Real time temperature and heart beat of an elderly people**

### 4.2.4 Monitoring Report of an elderly people

The elderly people monitored parameters are made daily, accurately indicating the time, date and the location of elderly people as shown on the table below. Trough this monitoring report, doctor can make daily, weekly and yearly report when necessary.

**Table 2: Elderly People Monitoring Report**




## 4.3 Results Discussion

The aim of this research is to design and prototype an IoT based remote health monitoring system for elderly people, tracking their location and send real time data using IoT. The system was successful designed, developed and tested.

The prototype system is wearable devices embedded with body temperature sensor, heart beat sensor and GPS sensor. The elderly people on different location wear the device and physiological data of elderly people are collected by the sensors continuously, sent to the created online dashboard and generate automatic graph based on temperature and heart beat variation data at time interval continuously, graph can go below or above the threshold values based on elderly people conditions, when the temperature or heart beat data reach the threshold set value means that there is a health issue; an automatic alert will be generated and SMS notification is sent to the caregiver and doctors. GPS sensor is used for tracking the elderly people location so that in case of emergency issue, the doctor can easily locate where the elderly people is located. The collected sensor data are sent to the created online dashboard to be stored, visualized and analyzed. The report of all sent data are accessed from myelder.techadopter.rw dashboard, Doctor access the elderly data from there, and make his/her analysis and decision depending on obtained physiological data.

# CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

From the study it is evident that it is important to monitor health conditions of elderly people. Different solutions have also been developed to make this a reality. However, existing solutions are note portable to African user and thus the need for customized solutions. The emerging technology of IoT is an area that can be exploited to make this a reality. The prototype results show that wearable sensor devices have the potential to monitor health conditions of elderly people while staying in their home. The project provides efficient health care services, particularly for elderly people with long term illness living alone and living alone in rural area. If implemented this will improve the quality of life of elderly people, increase health worker productivity and reduce overall health care cost.

## 5.2 Recommendation and Future work

### 5.2.1 Recommendation

The results from the previous sections prove our hypothesis that an IoT based system can be used to monitor the health conditions of elderly people with real time alerts to the caregiver or doctor are needed.

However, there is a need for an IoT architecture that will take into consideration and integrated with the existing systems. We therefore recommend a generic IoT architecture with five layers for integration with current health care systems namely data acquisition layer, transportation layer, data integration layer, application layer and business layer. We also recommend future researcher to think about using machine learning which will help in the prediction of diseases that can affect elderly people based on collected vital signs

### 5.2.2 Future work

The project prototype that was developed indicates that there are some limitations; there is security issue of the systems' hardware to be though about and resolved in the future work.

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