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KCA UNIVERSITY

SCHOOL OF COMPUTING AND INFORMATION MANAGEMENT

Masters of Science in Data Communications

Arduino Based Messaging System for Real Time Remote Health Monitoring of Patients

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By

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

I dedicate this work to my family for their love for me and great support towards my education.

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Abbreviations

IEEE	Institute of Electrical and Electronics Engineers
ITU	International Union of Telecommunication
IBM	International Business Machine corporation
WHO	World Health Organization
GSM	Global System for Mobile communication
GPRS	General Packet Radio Service
SMS	Short Message Service
SIM	Subscriber Identity Module
MT	Mobile Terminal
MSC	Mobile Switching Centre
MO	Mobile Originated
SMSC	SMS Centre
ESME	Extended Short Message Entity
VLR	Visitor Location Registration
GPS	Global Positioning System
RFID	Radio Frequency Identification
WLAN	Wireless Local Area Network
WBAN	Wireless Body Area Networks
WIMAX	Wireless Interoperability for Microwave Access
WPAN	Wireless Personal Area Network
WIFI	Wireless Fidelity
TDMA	Time Division Multiple Access
CVD	Cardiovascular Disease
ECG	Electrocardiography
EMG	Electromyography
EEG	Electroencephalogram
BP	Blood Pressure
PPG	PhotoPlethysmoGraph
HTML	Hyper Text Makeup Language
CSS	Cascading Style Sheets
SVG	Scalable Vector Graphics
MHz	Mega Hertz

Abstract

Health care provision remains a big challenge both in developing and developed countries. With increasing life expectancy a much larger percentage of the population will be dependent on others for their daily care in years to come. Lifestyle diseases are on the rise, with higher prevalence of diseases like diabetes, cardiovascular diseases, obesity and Hypertension, among many others. Extreme cases that need close observation can be done within the hospital setup other cases can be monitored remotely.

High cost medical provision is being experienced in both developing and developing countries, where total global health spending is expected to rise by an average of 5.3 percent a year by 2017. Most of the patients especially in poor countries result to an out-of-pocket expenditures on health.

Reseach has shown that ratio of physicians to people is 14:1,000 globally and 2.3:1,000 in Africa. The European Commission also points out that there will be a shortage of 230,000 physicians across the continent in the near future.

It is therefore necessary to work out alternative ways of monitoring patients without necessarily confining them in a hospital environment, hence the need for remote health monitoring systems and devices to reduce the workload on the already overloaded workforce in the health sectors. Advancement in sensor technologies, modes of communication and data transmission, data analytics systems and software are a key to success of such systems. For efficiency and reliability of transmissions different modes has to be included to avoid cases of data loss.

The Arduino based remote health monitoring system presented in this research dissertation allows remote transmission of physiological data to the health care givers. The device transmits via three modes, that is, Bluetooth, GSM-SMS and WIFI.

The device enables data to be accessed by the patient and the doctor, and sends alert message to emergency operators in case the threshold values are exceeded.

CHAPTER ONE

1.0 Introduction

Advances in sensor technology, personal mobile devices, and wireless broadband communications are enabling the development of an integrated personal mobile health monitoring system that can provide patients with useful tool to assess their own health and manage personal health information anytime and anywhere, (Verulkar & Limkar, 2012). As a result of this, people with special medical monitoring needs can be sent home and remotely monitored through the use of data logging medical sensors and a transmission base station, (Townsend, et al., 2011). Major obstacles for healthcare services are time and space between the providers and the patients, (Vouyioukas & Maglogiannis, 2012, Mehdia, et al., 2012). With the modern communication devices like the smart phones, this gap can be minimized in the sense that the medical devices are interconnected with the communication systems thus enabling the doctor to be in touch with the patients without necessarily meeting them physically. Seamless connectivity and high speed data transmission technologies, current and those under development are a major boost and a great hope for real time remote health monitoring, (IEEE Communication Society, 2015). Therefore the patient's health can be monitored remotely. Shahriyar, et al., (2009), emphasizes this by agreeing that the goal of mobile health care is to provide health care services to anyone at anytime, overcoming the constrains of place, time and character.

The main aim of health monitoring is to monitor one's health and identify a case where the individual's healthy state has been compromised. In a case where the status moves from a stable state to a point which is out of norm, then, measures can be taken to save life. In so doing cases of deaths which could have been avoided can be minimized by early intervention' (Jalaliniya & Pederson, 2012).

According to Verulkar & Limkar (2012), remote monitoring enables medical professionals to monitor a patient and can be used primarily for managing chronic diseases or specific conditions such as heart diseases, diabetes mellitus, or asthma.

In the recent past mobile computing and healthcare are areas which have gained popularity as many research look for ways of integrating the two for purposes of health monitoring. Such devices are aimed at improving communication among patients, physicians and caregivers. All these, is one of the applications of pervasive computing.

Pervasive computing is the concept that incorporates computation in our working and living environment in such a way so that the interaction between human and computational devices such as mobile devices or computers becomes extremely natural and the user can get multiple types of data in a totally transparent manner, (Shahriyar, et al., 2009).

Driven by consumers demand for more advanced applications and the emerging innovations in the wireless communication networks, mobile computing and wireless networks have made a significant growth technologically. We have had wide spread adoption of new powerful hand held devices, mobile phones and computers. Looking into Kenyan mobile population alone statistics in table 1.1 are obtained;

Table 1.1: Mobile Subscription in Kenya 1999-2015

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1,590,785	2,546,157	4,611,970	7,340,317	11,349,412	16,303,573	19,364,559	24,968,891	28,080,771	30,731,754	31,830,003	33,632,631	37,715,944

(Source; ITU, 2016, Oteri, et al., 2015)

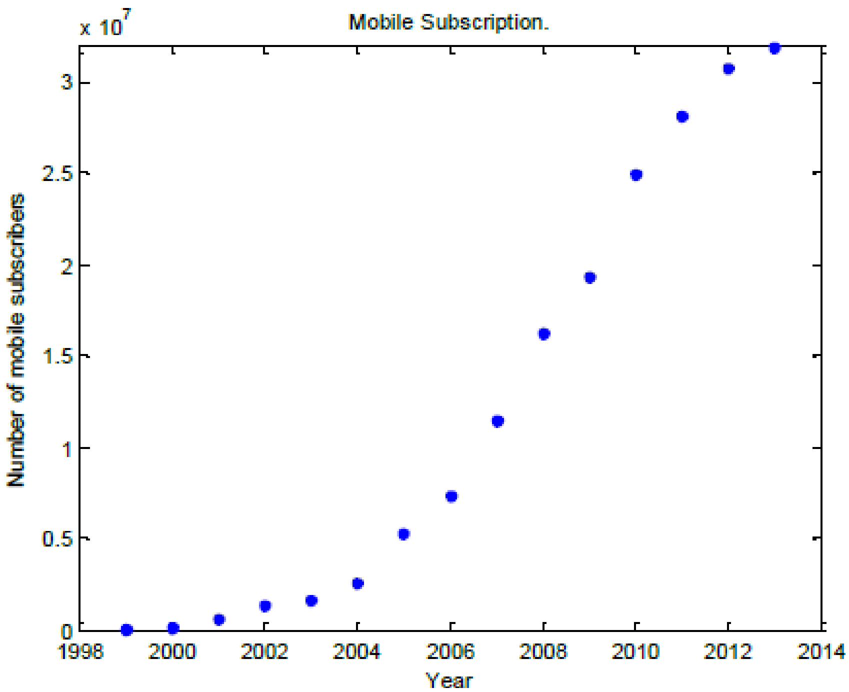

Figure 1.1: Mobile Subscription Trends Graph. Source;

(Oteri, et al., 2015)

As mobile devices have become an inseparable part of our life, it can integrate health care more seamlessly to our everyday life. It enables the delivery of accurate medical information anytime anywhere by means of mobile devices, (Shahriyar, et al., 2009).

Also with the current platforms, 3G and 4G, data transmission speeds have greatly improved. As pointed out by Vouyioukas & Maglogiannis (2012), the introduction of high speed data rate, wide bandwidth, digital and encrypted communication technology, makes possible the delivery of audio, video and waveform data to wherever and whenever needed.

This system is not only beneficial to the health givers and patients in terms of health monitoring but also takes care of people who have medical issues known to them but are unwilling and unable to go to physicians e.g. obese. In such cases the device can be personalized to the patient's needs and help in self monitoring, only visiting physicians when necessary. With the increase in number of people in need of health care compared to the number of the health care providers, Gay, et al., (2010), points out that the impending crisis in health care provision can be eased by remote monitoring systems.

Our system is aimed at acquiring the patients' data (temperature and heart rate) by use of temperature sensor and Photoplethysmogram for heart rate. The real time data will be transmitted to the doctor and in case threshold values are exceeded, the system will automatically contact the emergency team who will locate the patient through the GPS technology.

The system transmits the data via Bluetooth module to the patient's phone, GSM-SMS to the healthcare givers and WiFI to the internet

1.1 Background

For a functional health monitoring system, several technologies have to be integrated. These include sensors, signal processing and interpretation hardware and software, transmission technology and data storage systems. Signal acquisition can be either invasive or noninvasive type.

1.1.1 Sensor devices

Sensors play a big role in the acquisition of the physiological signals. A low sampling frequency for human physiological signals by the sensors is sufficient' (Cao, et al., 2009).

The choice the sensor however, depends largely on its application. Several sensors are available in the market for the different functions. Among many other sensors, we have, accelerometer and gyroscope for determining body orientation, ECG for checking heart activities, electromyography (EMG) for recording of muscle activities, and electroencephalography (EEG) electrodes for checking electrical activity of the brain. Others include; pulse oximetry for monitoring of oxygen level in the blood, blood pressure sensors, blood sugar, humidity, and temperature sensors, (Cao, et al., 2009).

Accelerometers are used to sense motion. In case of a fall this is the sensor to issue a signal. On the other hand, the Pulse oximetry sensor is used in determining the heart pulse rate and blood pressure by use of the photoplethysmograph (PPG) technique.

1.1.2 Data processing system

The system consist of the two parts; signal conditioning circuits and data interpretation. Signal conditioning is done using operational amplifiers. The amplifiers magnify the obtained signals from the sensors.

Data interpretation and decision making is achieved using the Arduino board which has a microcontroller chip for data processing. In this project the Arduino nano was programmed for processing of the data obtained from the sensors and decision making.

1.1.3 Wireless technologies for data transmission

Several wireless technologies are available for use in medical applications. Suitability of a given technology depends on a number of factors one of them the environment in which the device is to be used. Some of the technologies include Wireless personal Area Network (WPANs), WiMAX, Wireless Local Area Networks (WLANs), Wireless Body Area Networks (WBANs) and cellular systems (2G, 3G, 4G). (Mehdia, et al., 2012, Pattichis, et al., 2007, Cao, et al., 2009)

1.1.4 System requirements

Users for remote health monitoring systems have different expectations. The elderly prefer a system that will give life assistance features due to their physical status, (LV, et al., 2010). In this case such devices should provide services like reminders, alarms or alert signal in case of a fall etc. Jalaliniya & Pederson, 2012, found that besides other factors like real time data relay parents would prefer attractive casing for the device. Most users would like to consider a device that will enable real-time monitoring, cost effective, simple to use and reliable in communication, (Fraser, et al., 2014).

From the above discussion, for a system to qualify for remote health monitoring, and to be widely accepted, several factors have to be considered during design process. These may be categorized as;

1.1.4.1 Design factors

Efficiency: Efficiency in this case relates to efficiency in power consumption, efficiency of the data obtained by sensors, computation and reliable transmission protocol. The device should be able to utilize minimum power possible while at the same time being able to deliver this data with high efficiency. Data obtained by the sensors should also be free from external noise generated by the environment in which it operates.

Reliability: This refers to accuracy of data obtained by sensors, availability of the data when needed especially for real time data transmission. In general the data obtained and transmitted should be fault free i.e. there should be a high level of trust in the quality of data. As pointed out by Townsend, et al. (2011), reliability in medical monitoring system can be defined in terms of delays in the network and rate of loss of information. Medical data is sensitive; any misdiagnosis can cause unnecessary cost and even loss of life (Liang, et al., 2012).

Security of data: The data from the remote monitoring devices will be transmitted using wireless telecommunication technologies. As the technology advances, malicious attackers also advance with it and will try to compromise the accuracy, and the transmission of the data. Confidentiality of the data will also be affected. For example if an attacker intercepts transmission system for a heart patient, then the patient's life will be at risk. This might even cause loss of lives. During design of the devices for health monitoring one should therefore look into protocols that guarantee the security of data

1.1.4.2 Operational factors

Simplicity: From the user perspective the health monitoring system should be simple to use i.e. it should be user friendly in terms of operation. According to IBM report on health monitoring consumers of these devices need simple, intuitive, yet feature-rich devices, (Fraser, et al., 2014). Users should not be subjected to mastering sophisticated routines/procedures especially the ones with health problems which make them have difficult in remembering.

Portability: Users are inclined to reject devices that are large in size, weighty and not comfortable, (Liang, et al., 2012). Consumers will therefore need a device that will give them comfort and not course disturbance in his/her daily activities i.e. it should not be obstructive. The device should not unnecessarily disclose the patient's condition to everyone who comes in contact with him/her. This may make one suffer by being misjudged by people like employers, insurance providers etc (Townsend, et al., 2011)

Data sharing and feed back: The user will always want to know the results of a medical diagnosis. The remote health monitoring device should therefore be able to display the results not only to the medical caregiver but also the user. In addition after the caregiver has evaluated the results the user would also be interested to know if his condition is okay, improving or needs medical attention. The system in use should have such provisions so as to be trusted and accepted widely by consumers.

Privacy of data: Confidentiality of data is of great concern for most users.

Cost effectiveness: Most of the patients who need close monitoring of their health are already facing costs of maintaining their health. Making an expensive device will be of an additional cost to them and some will not be able to manage. Use of low cost devices to achieve the final objective should be of consideration.

Seamless connection: Connection of the system to the network should be of high efficiency and reliability. Delays, loss of data and lack of network signal can be some of the things that may endanger the life of the user of this device. A device that will use more than one type of transmission method will be more effective. For example a system may use either GPRS or SMS, in case data is not delivered by one an alternative takes over.

1.1.4.3 Policy and regulatory factors

West (2012), in his research on mobile devices in healthcare, noted that most patients want to employ digital and mobile technologies in medical care. The major issues, worrying a large number of interested clients is, privacy and security of data and acceptance by the players in the health services provision.

He points out that many are worried with lack of policy that will act as a guideline for insurance companies and also employers. There should be policies to guard users against victimization and protection of personal data.

As note by Ogao, et al. (2012), the major challenge in adaptability of health information is lack of interoperable systems and consensus on data standards. Interoperability can be achieved with coordination and cooperation of stakeholders.

Governments need to spearhead the formulation of regulations and policies on the quality and standards required for electronic device to be used for remote health monitoring.

1.2 Definitions

Oxford dictionary defines healthcare as the maintenance and improvement of physical and mental health, especially through the provision of medical services. In this case the provision of medical services is done by the health care givers. Healthcare monitoring system therefore refers to a system that helps the caregivers and other medical persons to keep track of the patients' progress (physical and mental) without the patient physically being at the health facility. A real-time system captures data as and transmits it to the caregivers within as it occurs.

1.3 Problem statement

Health care provision is a big challenge not only in developing countries but also in developed nations, in that the number of health care givers is being overpowered by the number of patients who need medical attention. According to 2014 Deloitte report on global health care, total global health spending was expected to rise by 2.6 percent in 2013 before accelerating to an average of 5.3 percent a year over the following four years (2014-2017). As per the WHO (2015) report on universal health coverage indicates that most of the patients especially in poor countries result to an out-of-pocket expenditures on health.

The population aged and patients with chronic diseases such as diabetes, heart failure, hypertension etc are increasing (McFerran, 2008, WHO, 2015). These diseases can be managed out of hospital by providing patients with remote monitoring devices (Stachura & Khasanshina, n.d.).

Inadequacy of human resources in health sector is so pronounced with rural areas being highly hit as many health practitioners prefer working in the urban areas (WHO, 2015)

The traditional monitoring systems fall short in many ways. These systems typically use equipments which are very costly, bulky, and uncomfortable to use due to wiring and cables which restrict user's movement and obstruct their normal activities (Vouyioukas & Maglogiannis, 2012).

1.4 Aim

The main aim of the researcher in this project is to come up with a prototype design of a model of real-time healthcare monitoring system that will utilize Bluetooth, GSM network and WIFI for transmission of data

1.5 Specific Objectives

Specifically to;

a). To carry out a comparative analysis of enabling technologies and requirements for a remote health monitoring system i.e. Emerging Mobile Access Networks, Sensor Connectivity, and Computing Systems

b) To identify the components and define the components for a remote health monitoring system

c) To design a portable device for transmission of patient's data via Bluetooth, SMS and WIFI.

d) To implement, test and validate the response of the system in terms data transmission in the various modes

1.6 Justification

As stated earlier, health care provision is a big challenge not only in developing countries but also in developed nations, in that the number of health care givers is being overpowered by the number of patients who need medical attention. As indicated in the 2014 report by Deloitte on Global health care; challenges and opportunities, global health spending is expected to accelerate by 5.3 percent between 2014 and 2017. The aging population with complications such as chronic diseases which need close monitoring is also increasing. According to Ross (2004), in 2025, 761 million of people in the world will be over 65 years. The WHO (2015) report indicates that the global ppopulation of the aged will increase by 50% by 2030. As pointed out by Lorenz, et al. (2007), though the risk of hypertension is uniformly distributed on all ages, the biggest group of patients is in the age of 50+. This trend will place enormous pressure on governments, health care delivery systems, insurers, and consumers in both developed and emerging markets to deal with issues such as an aging population, the rising prevalence of numerous chronic diseases, soaring costs, uneven quality, imbalanced access to care due to workforce shortages, infrastructure limitations and patient locations, and disruptive technologies, (Deloitte, 2014). There are 14 physicians for every 1,000 people globally and 2.3 for every 1,000 people in Africa (KPMG, 2012). For some chronic diseases like diabetics access to doctors in some countries like Kenya is a big problem, (McFerran, 2008). Globally, the number of doctors per 1,000 people is expected to remain virtually the same between 2012 and 2015. For instance, the United Kingdom, has a shortage of other health care professionals including general practitioners (GPs) and had an estimated shortage of 40,000 nurses in 2012. The European Commission also points out that there will be a shortage of 230,000 physicians across the continent in the near future, (Deloitte, 2014). With these worrying figures, personalized medical attention for patients is a big challenge. Providing care for these people will be a major challenge, hence it will be important in the coming years to develop technology which can reduce the workload on the caregivers.

The Royal College of nursing, UK (2012) report puts remote monitoring in three categories;

- One in which there is interaction between client and an expert
- One in which we have transmission of information through e-mail, text message or web-chat
- Lastly one in which a clinician is available to interpret and respond to information.

Moving health care to the home encourages patient engagement and enables them to become an integral part of their extended health care team. Remote monitoring empowers the patient to take common measurements such as blood pressure, sugar levels, weight etc (Telus Health Solutions, 2014).

A research done by Chung-Chih, et al., (2008), in Taiwan indicates that many people prefer living in familiar communities and surroundings as they receive health care. Patients will also want to receive immediate feedback on their health status. This is possible with devices that can collect data, interpret display to the patient and transmit to health care providers without the patient physically appearing in the hospital.

Advances in sensor technology, personal mobile devices, and wireless broadband communications are enabling the development of an integrated personal mobile health monitoring system that can provide patients with useful tool to assess their own health and manage personal health information anytime and anywhere (Verulkar & Limkar, 2012). The model presented in this report uses non-invasive sensors to obtain the physiological signals. These include; temperature sensor, heart rate monitor and blood pressure sensor. Many wireless transmission technologies are available for use in such a system. Examples are; GPRS, GSM, ZIGBEE, Bluetooth, Wi-Fi etc. In this model GSM-SMS technology is used. GSM utilizes 900 and 1800MHz frequencies and Time Division Multiple Access (TDMA) technology. The data is transmitted in digital form, (Chwan-Lu, et al., 2006). Large populations of Kenyans either have access or do posses a mobile phone with a GSM SIM card (Refer to table 1.1 & figure 1.1). SMS data uses low power transmission channel and the GSM encryption can protect SMS data (Chwan-Lu, et al., 2006).

According to West (2012), use of mobile devices improves worker productivity by reducing travel time, improving logistics, enabling faster decision making and improving communication. Therefore these benefits can also be experienced in medical health care sector by use of mobile devices to monitor patients' health.

The device discussed in this report is targeted at people who need close monitoring but do not necessarily have to be in the hospital environment. Such group includes; diabetics, kids and the elderly. In general the vulnerable group especially those with risk of high blood pressure which might lead to cardiovascular diseases (CVD). As noted by Jalaliniya & Pederson (2012), early childhood (defined as between 0 and 5 years of age) is one of the most critical developments of life. At this stage there are signs like coughs, cries, sneezes, increase in temperature, heart beat rate, reduced activity level etc that need attention. The signs are an indication of a problem in the health status of the child and if early precautions are not taken the parent may end up encountering more complicated situations in a child's health. With the current world where parents leave children with house-girls, day care facilities or with relatives, it is important that the parent may need to be in touch with the child's health status. Therefore wearable device with ability to transmit the signals on the current state is of great importance. We have other cases like stroke patients, epileptics, diabetic patients etc that also need monitoring and transmission of real-time data. Take a case of diabetic patients in Kenya. Though currently they have an electronic device to measure the sugar level from anywhere, they must have a note book to record the readings. What if the notebook is lost, misplaced or even rained on, this means the data is lost and the doctor has no progress report for his/her patient. A solution is where the electronic device can be connected to a device which can transmit this data to a remote storage location where the doctor can access without the patient physically going the health facility. This will also be convenient to both the patient and the doctor in that the doctor can give advice to the patient through phone call, email etc and only have the patient coming to the hospital in case of a critical situation that needs close monitoring. On the other hand the data obtained from the device can be useful in predicting cause of an ailment. For instance, the location data provided by the GPS can help identify diseases emanating from people in the same locality. With such data medical practitioners can easily investigate the trigger factors from that particular area. Remote health monitoring system if used could save not only individuals but also the governments a lot of medical costs (West, 2012).

1.6.1 Importance of the Research

This research will culminate in the development of an artifact that will be used to acquire patients' physiological data and transmit it to a remote recipient via SMS and WIFI.

Application of this research in health sector will help in monitoring of patients remotely, with only patients attending hospital checkups only when there is need or on doctor's recommendation.

1.7 Organization of the dissertation

This dissertation is organized as follows. Section one which has the introduction, the background information which gives a brief background of various methods available for bio-signal data acquisition, wireless technologies available for data transmission and the design requirements for patient monitoring system. Also included under section one, we have: general and specific objectives of the project, problem statement and justification.

Section two deals with the literature review in which, the related work and literature. Section three is the looks into the research methodologies, and tools related to the work in the project and implementation. The fourth part discusses the results and finally the fifth chapter gives conclusion and the recommendations.

CHAPTER TWO

2.0 Literature Review

2.1 Introduction

This research aims to investigate the applicability of remote health monitoring system in monitoring of patients with chronic diseases or need close monitoring without necessarily visiting health care providers in the hospital. Remote Patient monitoring refers to wide variety of technologies designed to managed and monitor a range of health conditions. These technologies can be used to slow progression of chronic diseases and ensure continued recovery after discharge from acute care conditions (Centre for Technology and Aging, 2014). Currently we have we have a number of research activities going on remote health monitoring systems. Most of the research done focus on various aspects that enable implementation of the systems, which include; sensor technologies, wireless transmission technologies and protocols, health care software applications, efficiency in power consumption etc. (Vouyioukas & Maglogiannis, 2012), (Shahriyar, et al., 2009). All these are driven by the demand from consumers for need of more applications that make life easier and comfortable. Bio-monitoring using mobile networks includes physiological monitoring of parameters such as heart rate, electrocardiogram (ECG), electroencephalogram, (EEG) monitoring, blood pressure, blood oximetry, and other physiological signals. We can also use other type of sensor to monitor physical activities such as movement, detection of fall, and tracking of location (Vouyioukas & Maglogiannis, 2012).

Remote health monitoring systems can either be Synchronous or asynchronous system. Asynchronous is one in which "Store and Forward" system is used. This means the data obtained is not transmitted as it comes, in this case the patient and the doctor can interact with the system independently.

However "Store and Forward" systems may not be applied for the provision of emergency electronic healthcare services in case of accidents. In addition the physicians seems to prefer in general the synchronous electronic healthcare systems since they offer interactive contact with the patient and simulate better the clinical examination (Vouyioukas & Maglogiannis, 2012). Therefore the Synchronous system is preferred for cases that need close monitoring and immediate feedback.

Issues raised in the design of remote health monitoring systems by most researchers are; cost of the medical monitoring devices, simplicity of use, notification in case of critical condition (Kumar, 2008). Sensitivity of Sensors, Effectiveness of Methods for Data Collection, Reliability of Data transfer, Ease of deployment, unobtrusiveness and mobility among other challenges (Ashraf & Aboul, 2011). Most health monitoring projects especially the ones using Body Area Networks (BAN) are using implanted sensors for collection of data and short range communication technologies for transmission of data. In this research project we apply the GSM wireless technology in which the Short Message Service (SMS) is used for sending data. SMS has been arguably the most popular wireless data service for cellular networks. Due to its ubiquitous availability and universal support by mobile handsets and cellular carriers, it is also being considered for emergency notification and other mission-critical applications (Meng, et al., 2007).

2.2 State of the Art in Remote Health monitoring

2.2.1 Remote Health Monitoring Enabling Technologies

A remote health monitoring systems can be split into the following blocks (Patel, et al., 2012);

1) Sensing and data collection system
2) Communication hardware and software
3) Data analysis techniques

New technologies in sensors, communication systems, data analytics and material science have been and are being developed to help in mitigating the challenges being faced by healthcare providers.

2.2.2.1 Sensor Technologies

Sensor devices are one of the solutions to health monitoring as they provide a link between the physical world and the electronic systems, (Cao, et al., 2009). In recent times we have witnessed advancement in sensor technology and electronic circuits with miniaturization being one of the major steps. This has made design and implementation of wearable systems easier, (Patel, et al., 2012). Various sensors are available for application the medical field. These sensors can be divided in two broad categories; invasive and non-invasive types

Invasive types of sensors are the ones which are either surgically implanted in body orifices or placed on the skin surface by incision. Features of Implantable sensors

- Are small in size,
- Lightweight,
- Require little power in their operation
- They should be compatible with body mass,
- Most importantly, they must not decay over time.
- Generally, they are more expensive and require a specialist to surgically implant them
- They require approval from relevant medical bodies before use

(Hong Kong; Medical device control office, 2016), (TE Connectivity Ltd, 2015)

Examples of invasive sensors;

Piezo sensor: Every time the patient moves, the sensor generates a signal. One of areas of application for this sensor is in the pacemaker. The pacemaker receives the generated signal and makes the heart beat at the desired pace. The signal from the sensor varies with different activities; walking, running, resting etc. For instance, in a case where the patient is resting, the signal will be zero and the pacemaker will lower the heart rate to minimal value (TE Connectivity Ltd, 2015).

A pair of matched thermistors: these are placed at the tip of a catheter and guided to different locations of the heart to measure blood flow. The blood flow is calculated by reading the difference of the resistance values of the two sensors.

Silicon MEMS-based disposable pressure sensors: are used to measure pressure and frequency of contraction during childbirth.

Oral and rectal probes: These are temperature sensors inserted into body cavities. They are covered with a soft coating material to protect the inner layer of the organs of the patient from sustaining damage due to contact (TE Connectivity Ltd, 2015).

Non-invasive types of sensors are ones which either do not touch the patient or contact intact skin only.

In most cases these are non-disposable sensors and can be used both at a hospital and home environments for continuous monitoring of patient's health status.

Some of the most common sensors are summarized in the table 2.1 below;

.

Sensor	Function	Sensor Location
ECG. **(Electrocardiogram)**	Measures the electrical activity of the heart to evaluate its function and identify any problems that might exist (The Heart rate and regularity of heartbeats, the size and position of the heart's chambers, and any damage present (Dowshen, 2013).	Arm, Legs and Chest
PPG **(photoplethysmograph)**	It is an Optical Device. It detects volumetric changes in blood in peripheral circulation (Tamura, et al., 2014). Used to Measure; Heart rate Blood Pressure Blood Oxygen saturation .	Finger, Earlobe
Respiration Sensor	Measures Breathing	Thorax, Abdomen
Accelerometer	Measures the acceleration relative to freefall in three axes; senses motion and direction of the motion in terms of the three axes i.e. x, y and z axes.	Leg. Arms, abdomen
Gyroscope	Measures the orientation of the body, based on the principles of angular momentum. Senses rotation.	Abdomen
Pulse oximetry	Measures ratio of changing absorbance of the red and infrared light passing from one side to the other of a thin part of the body's anatomy thus determining oxygen saturation in the blood.	
Carbon dioxide	Uses the infrared light and measures the absorption of the gas presented	
Blood sugar	Traditionally analyzes drops of blood from a finger tip, recently, uses non-invasive method including a near infrared spectroscopy, ultrasound, optical measurement at the eye, and the use of breath analysis	

Temperature	Uses a silicon integrated circuit to detect the temperature changes by measuring the resistance

Table 2.1: A Summary of Sensors

Choice of sensor for medical use depends on the application and the parameters to be monitored

2.2.2.2. Wireless Communication Technologies for Remote Heath Monitoring

We have a wide scope of wireless telecommunication technologies that can be exploited to achieve the dream of remote health care provision. Coexistence and cooperation of personal area technologies such as radio frequency identification (RFID), Bluetooth, ZiGBee and wireless sensor networks with large scale wireless networks such as 3G, Wi-Fi, WiMAX provide complete context-aware homecare applications if high quality services. Several issues that involve the common standards and protocols need to be addressed for a successful integration of these technologies (Vouyioukas & Karagiannis, 2011).

GSM is a cellular system of mobile communication network is a technology that is most widespread and adopted by many people in the world. Currently we have the use of 2G, 3G and 4G technologies. The evolution of mobile telecommunication systems has contributed to faster data transfer speeds making application in medical field very promising.

We also have satellite systems, WLAN, WiMax, metropolitan area networks" (WMANs) among many others (Pattichis, et al., 2007).

Summary of the technologies, specifications and application is provided in table 2.2.

Wireless Technology	Description
WIMAX	Worldwide Interoperability for Microwave Access, (WiMAX), is a technology based on the IEEE 802.16 standards. Has strong-security, Long distances wireless data transmission (up to 50km), high data rate (up to 70 Mbps). The standard incorporates several advanced radio transmission technologies such as adaptive modulation and coding (AMC), adaptive forward error correction (FEC),
WLAN	Wireless Local Area Network, introduced in 1997, also known as IEEE 802.11. The initial version evolved to IEEE 802.11a and IEEE 802.11b. IEEE 802.11a range is100 feet and 802.11b covers 350feet outdoors and 150 feet indoor. After the introducing of 802.11a and 802.11b, Wi-Fi alliance formed and started its work certifying wireless based devices. 802.11g, added in 2003 has a 54Mbps transmission capabilities working on 2.4GHz band at range of 350ft outdoors and 150 feet indoors
WPAN	Wireless Personal Area Network, uses ZigBee or Bluetooth standards. ZigBee (IEEE 802.15.4), is an ultra-low power and low-data rate standard. Used for monitoring and controlling applications. Devices using ZigBee are in sleep mode most of their time so as to save device's power. Bluetooth can be used for patient monitoring and tracking. WPAN can be used in hospital set up for real-time transmission and monitoring of patients' vital signs.
WBAN	Wireless Body Area Network, is a network formed by tiny, lightweight, ultra-low-power monitoring devices. Low power WBAN is used to monitor patients in critical conditions within hospital set up. WBAN can still be used in remote health monitoring where the device can transmit patients' vital signs to their physicians over internet in real-time.
RFID	The first RFID chips were approved by Food and Drug Administration in October 2004. This opened doors for applying RFID in medical applications.
Cellular Systems	(2.5G, 3G and beyond 3G) have the potential to greatly improve telemedicine services by extending the range of healthcare system, enhance the flexibility and heterogeneous network with an end-to-end telemedicine framework.

Table 2.2: A Summary of Wireless Technologies

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2.2.2.3 Data analysis Techniques

Data collected by medical sensors will only make sense if it is interpreted and presented in a simpler and understandable manner. This can be achieved by use of various data analysis and interpretation tools that help researchers visualize complex multidimensional data. These are available in the market either as proprietary or open source software.

A number of these tools are available for the application. Examples we have;

D3.js

D3. Is an abbreviation for 'Data Driven Documents', .This is a free and open source Data Visualization Software. It uses HTML, CSS, and SVG to render some amazing charts and diagrams. (Sharma, 2015)

FusionCharts

FusionCharts has probably the most exhaustive collection of charts and maps. It not only supports modern browsers, but also older browsers starting from IE 6.

FusionCharts supports both JSON and XML data formats, and you can export charts in PNG, JPEG, SVG or PDF. They have a nice collection of business dashboards and live demos for inspiration.

This tool is not open source and it is slightly expensive.

Chart.js

This is a tiny open source library that supports just six chart types: line, bar, radar, polar, pie and doughnut.

Leaflet

It is an open-source library developed for mobile-friendly interactive maps. It is extremely light with lots of features for making any kind of maps. It uses HTML5 and CSS3 for rendering maps, and works across all major desktop and mobile platforms.

Other tools for data analysis and visualization include; Datawrapper, Dygraphs, Tableau, RAW, Timeline js, etc (Sharma, 2015), (Boost Labs, 2016).

2.3.0 Global System for Mobile Communications (GSM)

Global System for Mobile Communications, GSM, is the international standard for mobile service. GSM is a digital cellular network that offers high mobility enabling users to freely roam worldwide and access any network supported by GSM.

GSM uses Time Division Multiple Access (TDMA) as its access scheme. At the time the standard was developed it offered much higher capacity than the current analog systems. It also allowed for a more optimal allocation of the radio spectrum, which therefore allows for a larger number of subscribers. GSM offers a number of services including voice communications, Short Message Service (SMS), fax, voice mail, and other supplemental services such as call forwarding and caller ID. GSM has the following bands; GSM. 450 MHz, 850 MHZ, 900 MHz, 1800 MHz, and 1900 MHz. Some bands also have Extended GSM (EGSM) bands added to them, increasing the amount of spectrum available for each band. (Scourias, 1994)

2.3.1 GSM-SMS Technology

SMS messages are transmitted over the Common Channel Signaling System 7 (SS7). SS7 is a global standard that defines the procedures and protocols for exchanging information among network elements of wireline and wireless telephone carriers. (Katankar & Thakare, 2010)

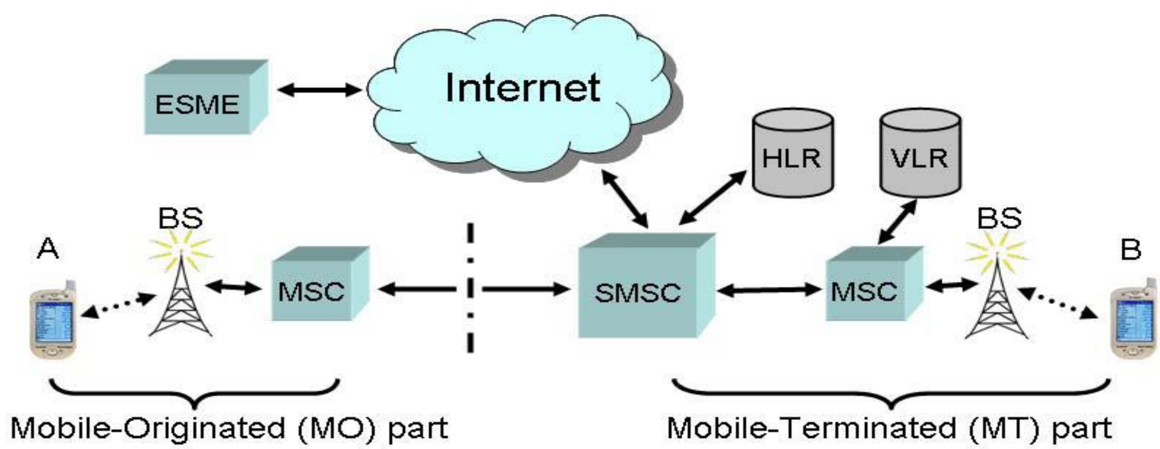


Figure 2.1: A typical Network of SMS Architecture

As in figure 2.1 above, the network architecture consists of two segments that are central to the SMS model of operation: the Mobile Originated (MO) part, which includes the mobile handset of the sender, a base station that provides the radio infrastructure for wireless communications, and the originating Mobile Switching Center (MSC) that routes and switches all traffic into and out of the cellular system on behalf of the sender. (Shanyora & Chaitanya, 2013)

The other segment, the Mobile Terminating (MT) part, includes a base station and the terminating MSC for the receiver, as well as a centralized store-and-forward server known as SMS Center (SMSC), responsible for accepting and storing messages, retrieving account status, and forwarding messages to the intended recipients. (Katankar & Thakare, 2010)

Though the Short Message Service has been popularized by the exchange of text messages among cell phone users, it has been increasingly used by businesses as a low-cost bearer to deliver various types of content. SMS can also be interface to the Internet (Meng, 2007).

2.4 State of Practice

2.4.1 Current technology and related work

Personal health care is one of emerged areas of research and as pointed out by Ziyu (2010), health monitoring devices can be classified into three categories: first group which records signal and takes offline action, second group which performs remote real-time data processing and third group which provides local real-time processing.

Personalized mobile health monitoring for elderly was designed to determine the current blood pressure and pulse rate of the elderly. The system then alerts the patient in case critical values are recorded. It also checks the battery levels to avoid the disconnection of the sensors (Lorenz, et al., 2007).

The system was mainly created for the elderly who in many cases have problems with their sight; in this case the readings were put at 36pt for comfortable reading by the patient. It also uses a screen size of 640x480pxs. In case of an alarm, the personal digital assistant or smart phone of the patient vibrates.

The author points out that some of the parameters obtained by the device and displayed, for example the oxygen level could not make sense to the patient. He also notes that the vibration alarm often caused panic to some patients (Lorenz, et al., 2007).

Shahriyar, R. et al, (2009), have developed an Intelligent Heath Monitoring System (IHMS), which is of three main components; wearable biosensors, local server and central remote server. The wearable device collects data and sends to local server via Bluetooth, which in turn sends to remote central intelligent medical server. The intelligent server mines the data using data mining techniques such as neural nets.

Another device is the icare, which is a mobile health monitoring system for the elderly, which combines mobile computing, wireless sensor technology and web technologies to offer real time health monitoring for the elderly. It is an improvement to Lorenz's model in that web technology has been included and also allows the doctors to set thresholds remotely.

One other unique feature in this model is the inclusion of a reminder for medicine and weather conditions to the elderly in observation (Ziyu, L. et al, 2010).

The Georgia Tech Wearable Motherboard (Georgia Institute of Technology, 2009), is a high tech vest that uses optical fibers to detect bullet wounds and monitor the body vital signs during combat conditions.

The Georgia Tech Wearable Motherboard (Smart Shirt) provides an extremely versatile framework for the incorporation of sensing, monitoring and information processing devices.

Real time health monitoring using GPRS technology is a proposed system by Shubhangi and Maruti from Mumbai University. It also uses Bluetooth technology to transmit to smart phone then to a server where threshold values are set. In case of alarm, the system sends SMS to the doctor and relative of the patient. (Shubhangi M and Maruti L, 2012)

Another research is the Wearable Kids' Health Monitoring System on Smart Phone (KiMS), developed by Jalaliniya, (2009). It uses the same concept as the Shubhangi's model but it is aimed at monitoring kids' health.

2.4.2 Mobile phone applications and Biosensors

Currently we have more than 97,000 mHealth applications listed on app stores, majority of which are general health and fitness apps that facilitate both the tracking of health parameters by private users, and provide users with basic health and fitness related information as well as guidance. (Mobile Health Market Report 2013-2017)

Since 1956 when we had the invention of biosensors by Leland Clark Jnr, we have had a significant development and improvements on the sensors. Technological advances have led to miniaturization of these sensors. Currently we have sensors which can be directly linked to mobile phones and used to monitor physiological changes.

Mobile Health applications make more and more use of external sensors to track a range of health metrics, such as blood pressure, heart rate, glucose level, medication compliance and more. They connect with the corresponding app via Bluetooth, WiFi or USB. The apps' analyzes the data being monitored by the sensors, displays and shares it (Mobile Health Market Report 2013-2017).

According to Mobile Health Report, the revenue generated with sensors connecting to an app will reach $5.6 Billion by 2017. The market will grow by 69% (CAGR) over the next 5 years. 61 Million Sensors will be shipped to mHealth app users in 2017.

2.4 Evaluation of Research Methodologies

2.4.1 Evaluation of current methods

Research methodology is a systematic way of solving a research problem. It is a science of learning how research is done scientifically (Kothari & Garg, 2014). There are two basic approaches to research viz., Quantitative approach and Qualitative approach.

2.4.1.1 Quantitative research

This approach involves the generation of data in quantitative form which can be subjected to rigorous quantitative analysis in a formal and rigid fashion. This approach can be further sub-classified into inferential, experimental and simulation approaches to research.

Inferential approach

The purpose of inferential approach to research is to form a data base from which to infer characteristics or relationships of population. This usually means survey research where a sample of population is studied (questioned or observed) to determine its characteristics, and it is then inferred that the population has the same characteristics (Kothari & Garg, 2014).

Simulation approach

Simulation approach involves the construction of an artificial environment within which relevant information and data can be generated. it is a way of representing reality in different forms using computer software, (Wilson & Corlett, 2002). It is a method that helps us view events under study in different environments and factors, and obtain insight to simple and even complex phenomena. This might not be possible with other methods. The simulation program represents an actual system or environment.

This method involves use of a simulation program to represent an actual system.

Strengths of Simulation approach:

- It provides the researcher with a practical feedback on efficiency and correctness of a design. The results can be used for implementation of real world systems.
- It allows the researcher to view a problem from different angles and levels so as to understand the behavior of a system. (Craig, n.d.)
- Helps to find un-expected behavior in the system
- It enables the researcher to perform the `What-If' analysis. (Craig, n.d.), (Xiannong, 2002)

Although it saves time and resources, this method is only an estimate; the answers provided may not be accurate. The method does not produce an actual or tangible system and it's sometimes difficult to interpret the simulation results. (Xiannong, 2002)

Experimental approach

Experimental approach is characterized by much greater control over the research environment and in this case some variables are manipulated to observe their effect on other variables (Kothari & Garg, 2014).

2.4.1.2 Qualitative research

Qualitative approach to research is concerned with subjective assessment of attitudes, opinions and behavior. Research in such a situation is a function of researcher's insights and impressions.

Such an approach to research generates results either in non-quantitative form or in the form which are not subjected to rigorous quantitative analysis. Generally, the techniques of focus group interviews, projective techniques and depth interviews are used (Kothari & Garg, 2014).

Qualitative versus Quantitative research

Table 2.3: Qualitative versus Quantitative research

Criteria	Qualitative	Quantitative
Purpose	To understand & interpret social interactions.	To test hypotheses, look at cause & effect, & make predictions .
Approach to Inquiry	subjective, holistic, process- oriented	Objective, focused, outcome- oriented
Variables	Study of the whole, not variables.	Specific variables studied
Research Setting	Controlled setting not as important	Controlled to the degree possible
Sampling	Smaller & not randomly selected.	Larger & randomly selected.
Measurement/type of data	Words, images, or objects	Numbers and statistics.
Role of Researcher	Researcher & their biases may be known to participants in the study, & participant characteristics may be known to the researcher.	Researcher & their biases are not known to participants in the study, & participant characteristics are deliberately hidden from the researcher (double blind studies)
Form of data collected	Qualitative data such as open-ended responses, interviews, participant observations, field notes, & reflections	Quantitative data based on precise measurements using structured & validated data- collection instruments
Type of Data Analysis	Raw data are in words. Essentially ongoing, involves using the observations/comments to come to a	Raw data are numbers Performed at end of study, involves statistics (using numbers to come to conclusions).

Criteria	Qualitative	Quantitative
	conclusion.	
Data Interpretation	Narrative report with contextual description & direct quotations from research participants.	Statistical report with correlations, comparisons of means, & statistical significance of findings.
Results	Particular or specialized findings that is less generalizable.	Generalizable findings that can be applied to other populations.

Source; (Xavier University Library, 2012), (Diffen.com, n.d.)

For purposes of this research, qualitative analysis was used to carry out a comparative analysis of various sensor technologies and wireless technologies that enable implementation of the system.

Experimental approach was applied to give a systematic approach in the design, implementation and testing of the artifact while Quantitative approach is then used to give an explanation to the measurements obtained.

2.6 Problematic Issues (Critique of the Literature)

As noted earlier we have increase in number of patients that need close monitoring thus putting pressure on health care providers, however currently we lack universal established guideline on manufacture of the remote health monitoring devices, general use and even standard way of handling the data.

Most of the devices are still under research level, with the wearable devices currently in the market only being used at personalized level with no transmission to health care providers for medical use.

The patient monitoring requirements include; periodic transmission of vital signs and transmission of alerting signals when threshold values are exceeded, or when device battery drops below a level, however most of the devices under research rely on one mode of transmission. The wearable devices like the smart watch and smart phones with capabilities of physiological data acquisition are using Bluetooth only as a transmission mode or utilizing the store and forward technique, hence no real time data.

A single mode of data transmission may not be sufficient due to reliability issues. Therefore, there is need to have alternative modes of transmission just in case one mode fails the data will not be lost. (Varshney, U. 2006).

CHAPTER 3:

3.0 RESEARCH METHODOLOGY

3.1 Introduction

The main aim of this research project was to design and implement an artifact to acquire physiological data from a patient under observation and send to a remote recipient, in this case a health care giver. This chapter discusses the methodology used to be able to achieve the outlined objectives of this research project, the implementation process and testing of the artifact. To achieve this, different sources of information are used. These include; books, journals, websites, conference proceedings and white papers.

3.2 Proposed Methodology

The goal of this research is to investigate how sensors and wireless communication technologies can be interconnected to enhance remote health monitoring of patients and implement an artifact for collection and transmission of data. Therefore qualitative analysis was used to carry out a comparative analysis of various sensor technologies and wireless technologies that enable implementation of the system.

Experimental approach was applied to give a systematic approach in the design, implementation and testing of the artifact

Quantitative approach is then used to give an explanation to the measurements obtained.

Design of the artifact involves the following;

- Identifying the various components to be used in the design (Sensors, Arduino board, GSM module, WIFI module etc)
- Programming the Arduino board C language code, to process and transmit the data acquired.
- Creating an online account on the Thingspeak web site for receiving and display of data send from the device via WIFI module.

3.4 Artifact Design

After design and implementation of the artifact, it has to undergo testing and evaluation. In this research, the researcher resolved to use real components for testing purposes.

3.5 The conceptual model

This section outlines the proposed model for acquisition and transmission of data to enable remote health monitoring of patients.

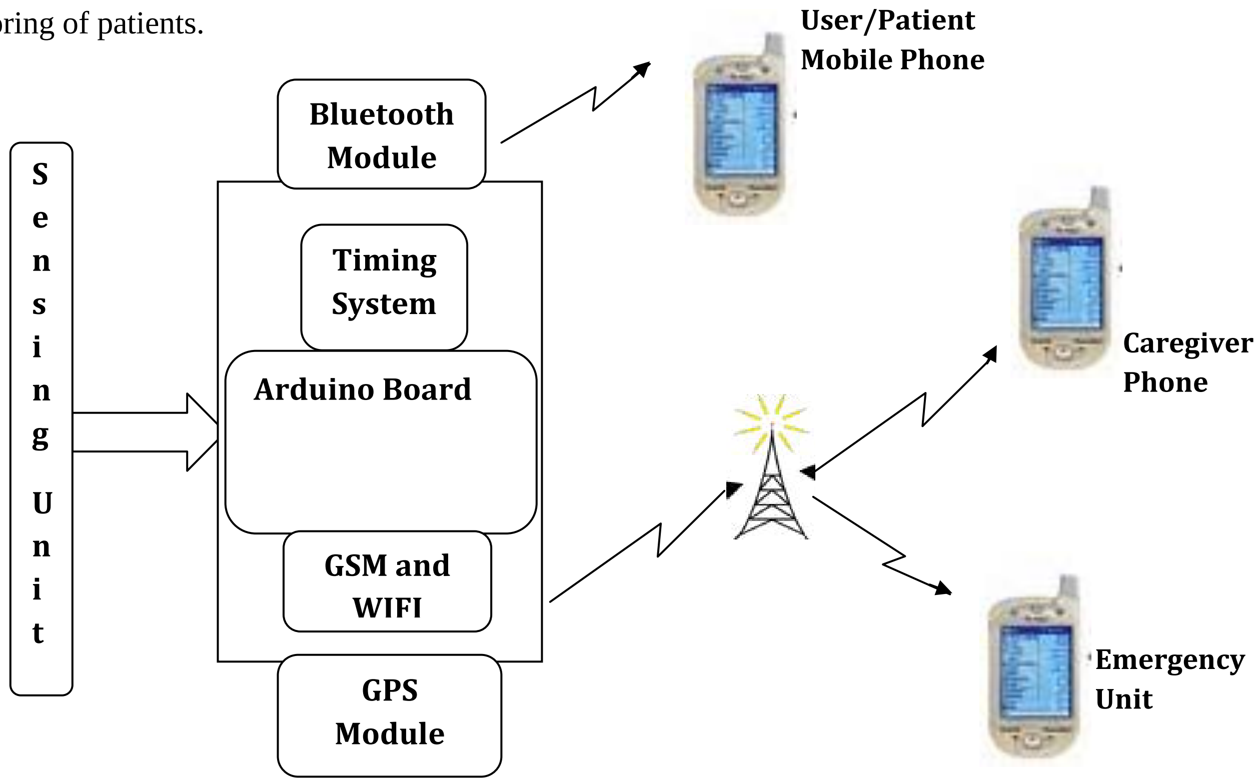


Figure 3.1: Conceptual Model

The proposed model shows the relationship between various elements of the system and how they interact to help achieve the goal of data transmission to a remote recipient. The conceptual model was developed after literature review. Several ideas have been combined to develop the system and therefore ideas used are not new. Shown in figure 3.1, is the conceptual model used for the purposes of this research.

3.6 Implementation

This section covers the design specification of the Arduino based Real Time Health Monitoring System. The researcher outlines the requirements and specifications of each component from the theoretical point of view and actual system after implementation. Testing of the system is done to verify its applicability in transmission of data. Figure 3.2 shows block diagram of the system.

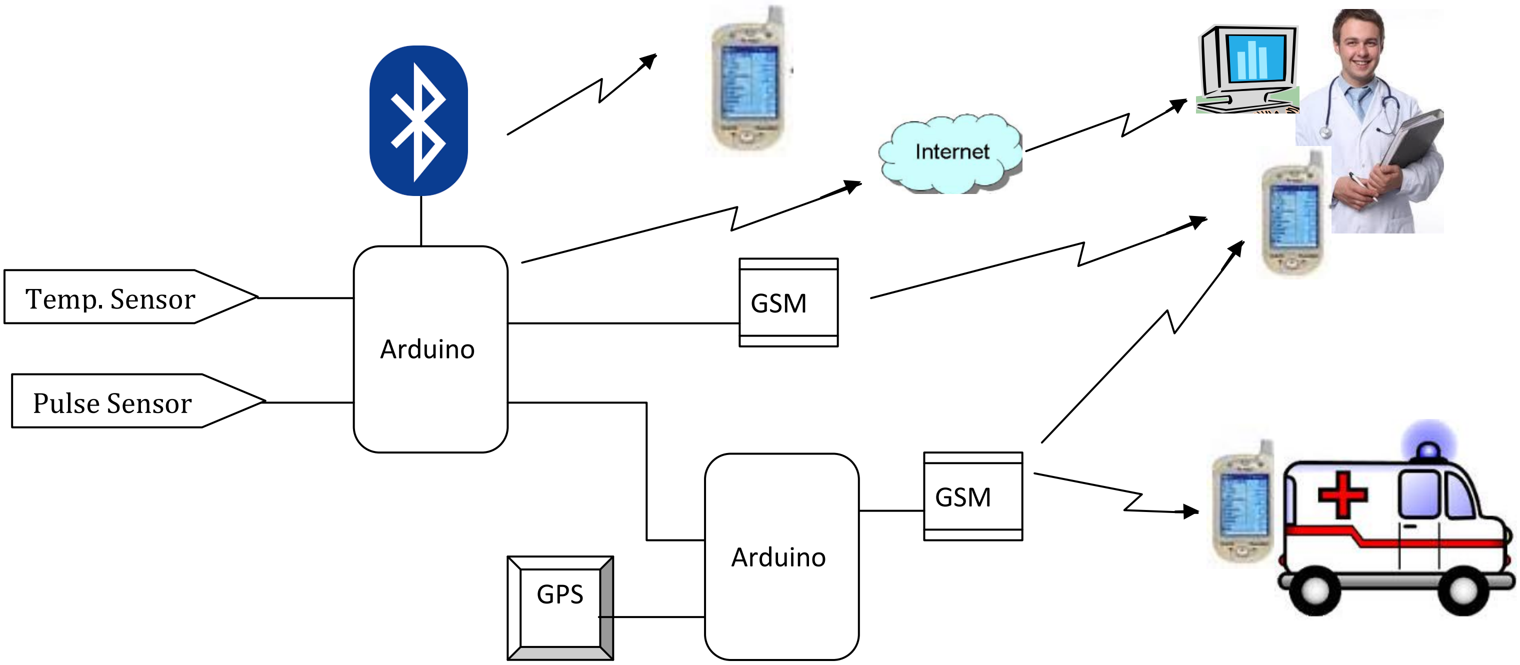


Figure 3.2 Implementation Block diagram

This includes the physiological signals sensors. These are Pulse/heart rate and temperature sensors.

3.6.0 Choice of Components

3.6.1 Sensing Unit

3.6.1.1 Amped Pulse Sensor

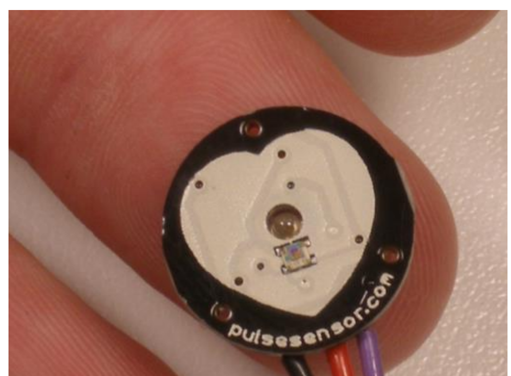


Figure 3.3: Amped Pulse Sensor

Amped Pulse Sensor is a well-designed plug-and-play heart-rate sensor for Arduino. It is a simple sensor that can be used by mobile developers who want to incorporate heart rate data in their projects. The sensor has three leads Positive, negative and signal leads.

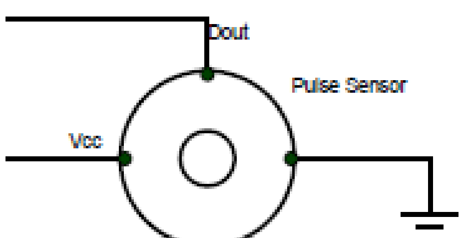


Figure 3.4: Pin out Diagram

The sensor comes with an open source code for Arduino and a processing code for graphical display of heart rate.

The researcher in this research project, modified the code to obtain and covert the heart rate into discrete values, print them on serial monitor, and also forward them for transmission via Bluetooth and GSM instead of graphical display on a computer.

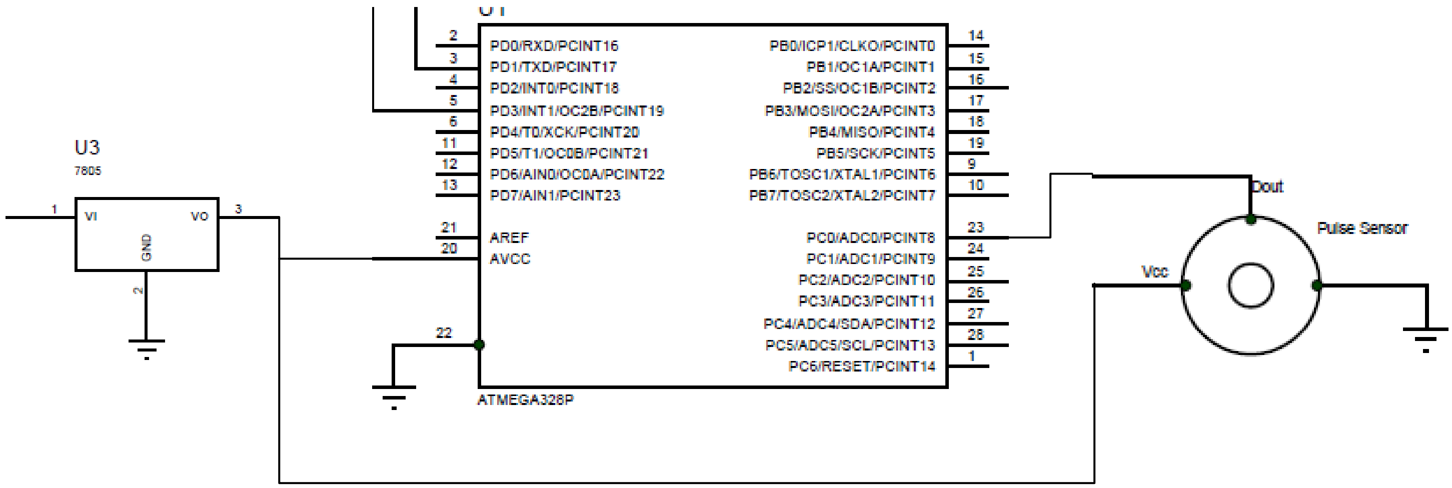


Figure 3.5: Pulse Sensor Connections

3.6.1.2 Temperature Sensor.

Temperature sensors are used to sense/detect heat or temperature. They measure the amount heat energy generated by a given object thus enabling us to see any physical change caused by effects of temperature. We have different types of temperature sensors;

- Contact Temperature Sensors: - these types need to have physical contact with the object whose temperature is being measured.
- Non-contact Temperature Sensors: - These types use convection and radiation to detect changes in temperature.

The temperature sensors can further be divided into; electro-mechanical (e.g. Thermostat), Resistive (e.g. Resistive Temperature Detectors, RTD) and Electronic (e.g. Thermistor, LM35)

For this research project LM35 Precision Centigrade Temperature Sensor was used.

Features description

The LM35 series are precision integrated-circuit temperature sensor, with an output voltage linearly proportional to the Centigrade temperature. Thus the LM35 has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling.

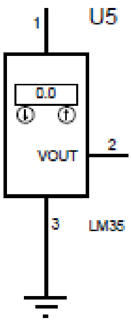


Figure 3.6: LM35 Schematic Diagram

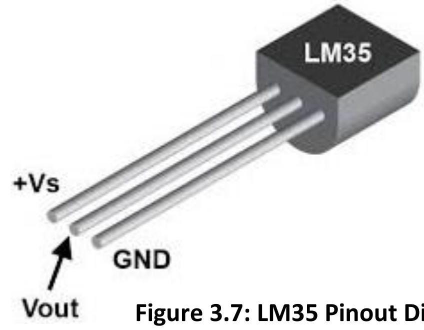


Figure 3.7: LM35 Pinout Diagram

The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to +150°C temperature range. More details on features are provided in appendix IV

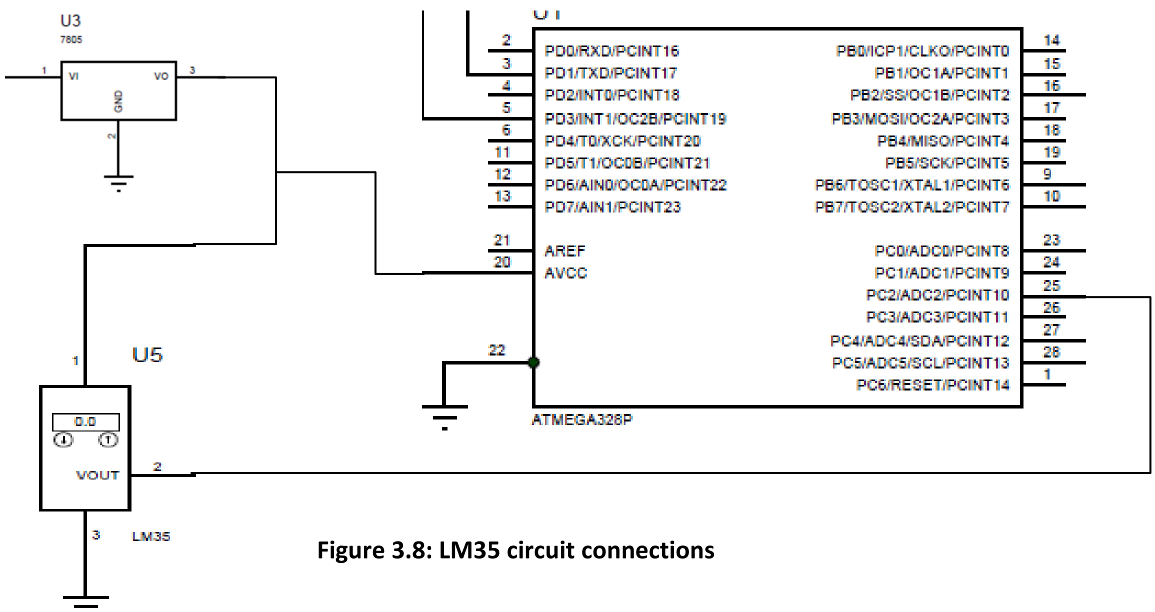


Figure 3.8: LM35 circuit connections

3.6.2 Processing Unit

3.6.2.1 Arduino Board

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. The heart of our Arduino is a microcontroller. Arduino boards are able to accept inputs and give an output that can be used to activate other devices. This can be done by telling the board what to do by giving it appropriate instructions in a programme. This can be done using Arduino programming language and the Arduino Software (IDE), based on Processing. The rest of the components on the board are concerned with providing the board with power and allowing it to communicate with other input/output devices.

The board has a processor, a Random Access Memory (RAM) for holding data, Erasable Programmable Read-Only Memory (EPROM) or Flash memory for holding our programs. It also has input and output pins for receiving and sending signals respectively and act as a link between microcontroller and the rest of the electronics. (ARDUINO, 2016).

We have different types of Arduino boards but for this project Arduino Nano is used because of its small size which makes the whole system more portable

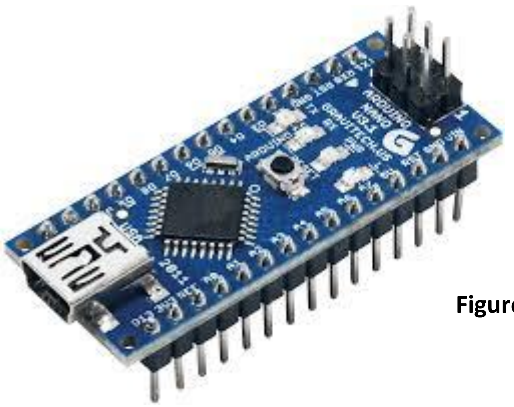


Figure 3.9: Arduino Nano

Features and specifications of the board used are summarized in the table below

Table 3.1 : Arduino Nano Specifications

Component	**Specifications**
• Microcontroller	• Atmel ATmega168 or ATmega328
• Operating Voltage (logic level)	• 5 V
• Input Voltage (recommended)	• 7-12 V
• Input Voltage (limits)	• 6-20 V
• Digital I/O	• Pins 14 (of which 6 provide PWM output)
• Analog Input Pins	• 8 DC
• Current per I/O Pin	• 40 mA
• Flash Memory	• 16 KB (ATmega168) or 32 KB (ATmega328) of which 2KB used. by boot-loader SRAM 1 KB (ATmega168) or 2 KB (ATmega328)
• EEPROM	• 512 bytes (ATmega168) or 1 KB (ATmega328)
• Clock Speed	• 16 MHz Dimensions 0.73" x 1.70"

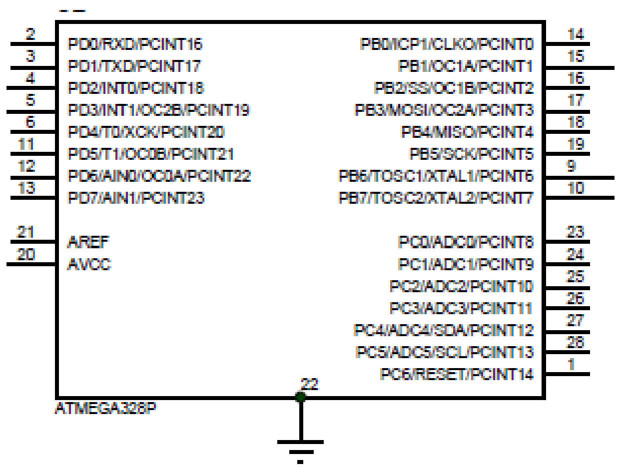


Figure 3.10: ATmega 328

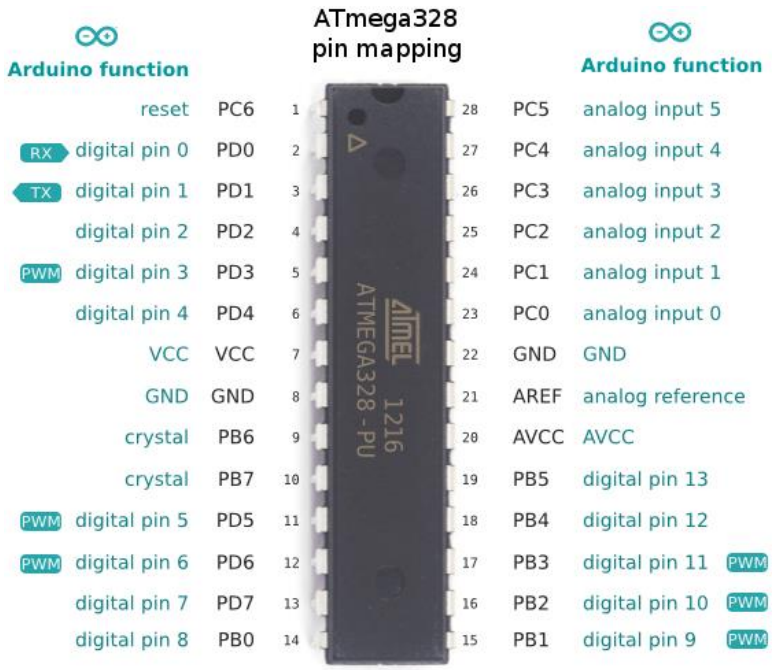


Figure 3.11: ATmega 328 Pin Mapping

3.6.2.2 Timer Module

The Real Time Clock (RTC) module is used to keep track of the current time and that can be used in order to program actions at a certain time. Most RTCs use a crystal oscillator whose frequency is 32.768 kHz (same frequency used in quartz clocks and watches).

RTC can continue to operate in any sleep mode, so it can be used to wake up the device from sleep modes in a programmed way. A real time clock has been used to provide an accurate date and time with respect to data transmitted by both GSM and Bluetooth shields. Real time clock (RTC) keeps the time going even when the Arduino is unplugged. The connection is as shown in the table below

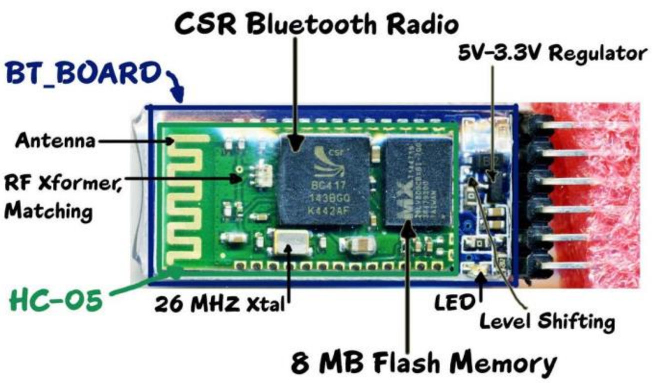
Table 3.2: RTC Module Specifications

MODULE	ARDUINO
GND	GND
VCC	VCC DV DC
SDA	A5
SCL	A4

3.6.3 Communication Unit

3.6.3.1 Bluetooth Module

A Bluetooth module is used in devices to enable wireless communication between devices which are a few metres apart. The devices are physically detached from one another but are wirelessly connected.



The module allows you to control your Arduino from your mobile phone or other Bluetooth enabled device through simple Serial commands.

The diagram below shows a typical connection for communication between microcontroller and Bluetooth module;

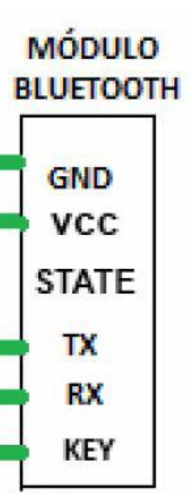


Figure 3.13: Bluetooth connections

3.6.3.2 GPS Module/Shield

A Global Positioning System (GPS) is a navigation device. The device is capable of communicating with GPS satellites, and then uses the received information to accurately calculate its geographical location. The device can perform in all weather conditions anywhere near or on the Earth.

3.6.3.3 GSM Module

The Arduino GSM Shield is capable of send/receive SMS, and Call/receive calls. A SIM card is plugged into the module, and with appropriate instructions it will be able to control the world around you.

We have various types of GSM shields offering different specifications and a developer has a choice as per the project requirements or personal preferences.

In this research project SIM 800L is used. SIM800L is a quad-band GSM/GPRS module. It works in the frequencies of GSM850MHz, EGSM900MHz, DCS1800MHz and PCS1900MHz. It is of small size which makes it suitable in projects requiring minimal space utilization.

It is designed with power saving techniques so that the current consumption is as low as 0.7mA when in sleep mode. Transmitting power is 2W at GSM850MHz and EGSM900MHz, and 1W at DCS1800MHz and PCS1900MHz. Figure 3.14 below shows pin configuration for the SIM800L.

Figure 3.14: SIM800L Pin Mapping

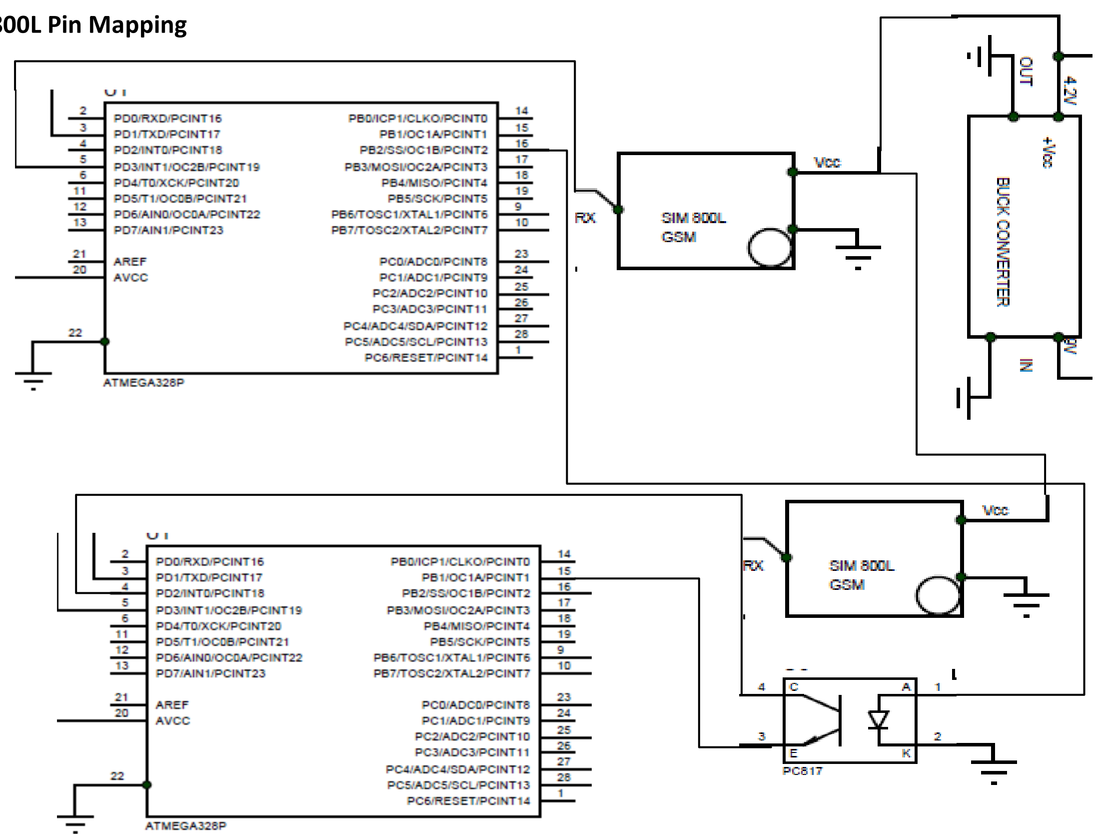


Figure 3.15: SIM800L Circuit connection

Figure 3.15, shows a two sets of circuit cascaded so that the first activates the second. The system uses two GSM modules for transmission of data; one for the normal readings that is the Heart rate and temperature, while the second set is activated when the values exceed the Threshold values. The later set up sends GPS coordinates and emergency alert message to the emergency operators and the caregivers.

3.6.3.4 The WIFI Module

A WIFI module is used to connect to the internet thus enabling data transmission to a web server. The module can also be programmed to act as an access point. We have a variety of modules in the market for instance the ESP8266 series which has different boards with a number of features and capabilities.

The ESP8266 WiFi Module which is a self contained System On Chip (SOC) with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network is used in this research project. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware

Figure 3.16: ESP8266 WIFI Module

3.6.4 Power supply

This system was designed to use an external power supply and in this case provided by a 9 Volts dry cell. The system has various components with varied power specifications. The Pulse sensor, Temperature sensor, Bluetooth, RTC module, and the Arduino boards require a voltage of 5V. Therefore voltage regulator, IC 7805 was used to achieve this.

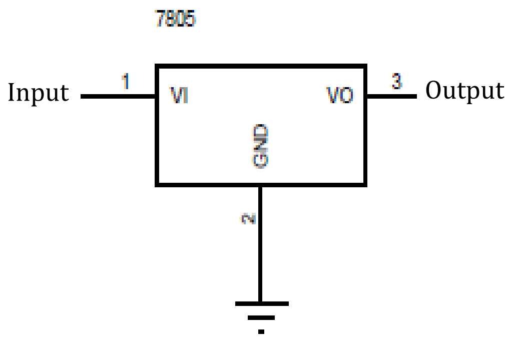


Figure 3.17: LM7805 Schematic Diagram

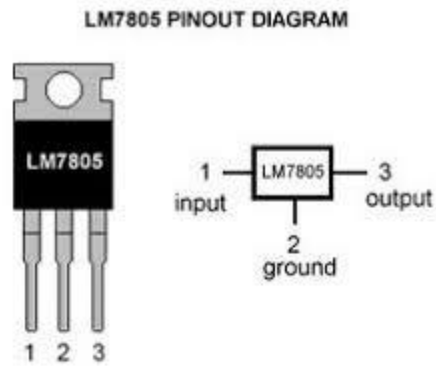


Figure 3.18: LM7805 Pinout Diagram

The GSM module requires a voltage supply of range 3.7 – 4.2 volts. This is obtained by use of a LM2596 buck converter step down power module.

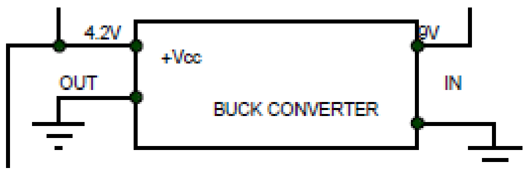


Figure 3.19: Buck Converter

A buck converter (step down converter) is a DC-to-DC power converter. It steps down voltage while stepping up current from its supply to the output.

3.6.5 Mobile Station (MS)

This part is not designed by the researcher but an existing systems provided by mobile phone service provider and mobile phone manufacturer is used The Mobile Station (MS) is made up of two components:

3.6.5.1 Mobile Equipment (ME)

This refers to the physical phone. The phone must be able to operate on a GSM network.

Three mobile phone terminals are used for this project. The first if for the patient, the second is for the doctor and the third mobile phone is for an emergency operator in this case representing ambulance emergency services.

We have mobile applications developed for receiving data via Bluetooth transmitter for the patient. The doctor's phone has an application that receives an SMS from the device. The SMS mobile number has to be entered in the mobile app, which in turn creates a folder that will be storing data from a device allocated to a particular patient.

3.6.5.2 Base Transceiver Station (BTS)

The Base Transceiver Station (BTS**)** are network equipment that facilitates wireless communication between a device and network. It consists of antennas, transceivers, duplexers and amplifiers

It handles speech encoding, encryption, multiplexing (*TDMA*), and modulation/demodulation of the radio signals

3.6.5.3 Mobile Switching Center (MSC)

The MSC is the heart of the GSM network. It handles call routing, call setup, and basic switching functions. An MSC handles multiple BSCs and also interfaces with other MSC's and registers.

3.7 Circuit Diagram

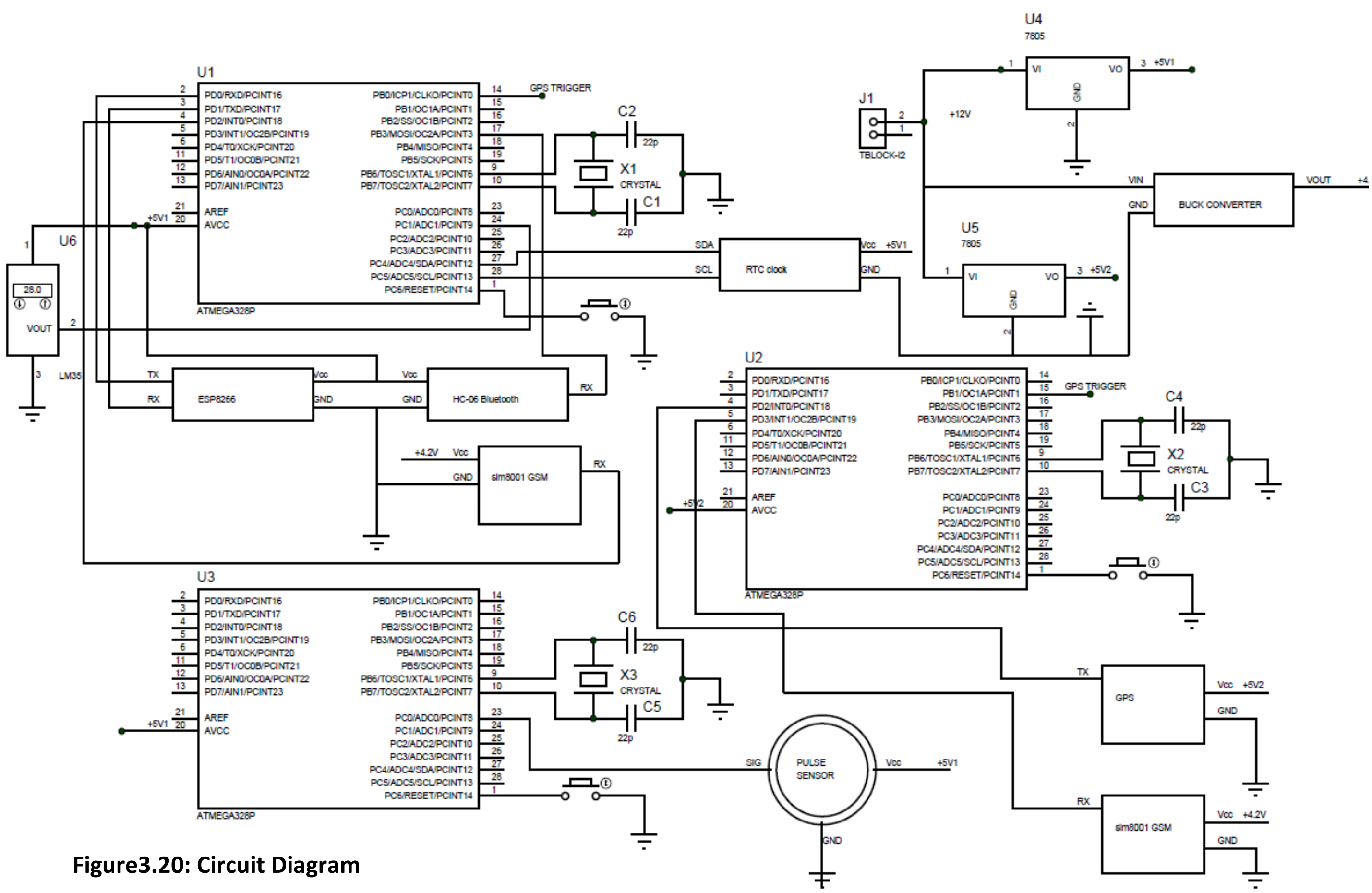


Figure3.20: Circuit Diagram

3.8 Software Design and Implementation

The flow of information in the system is represented by the flow chart below.

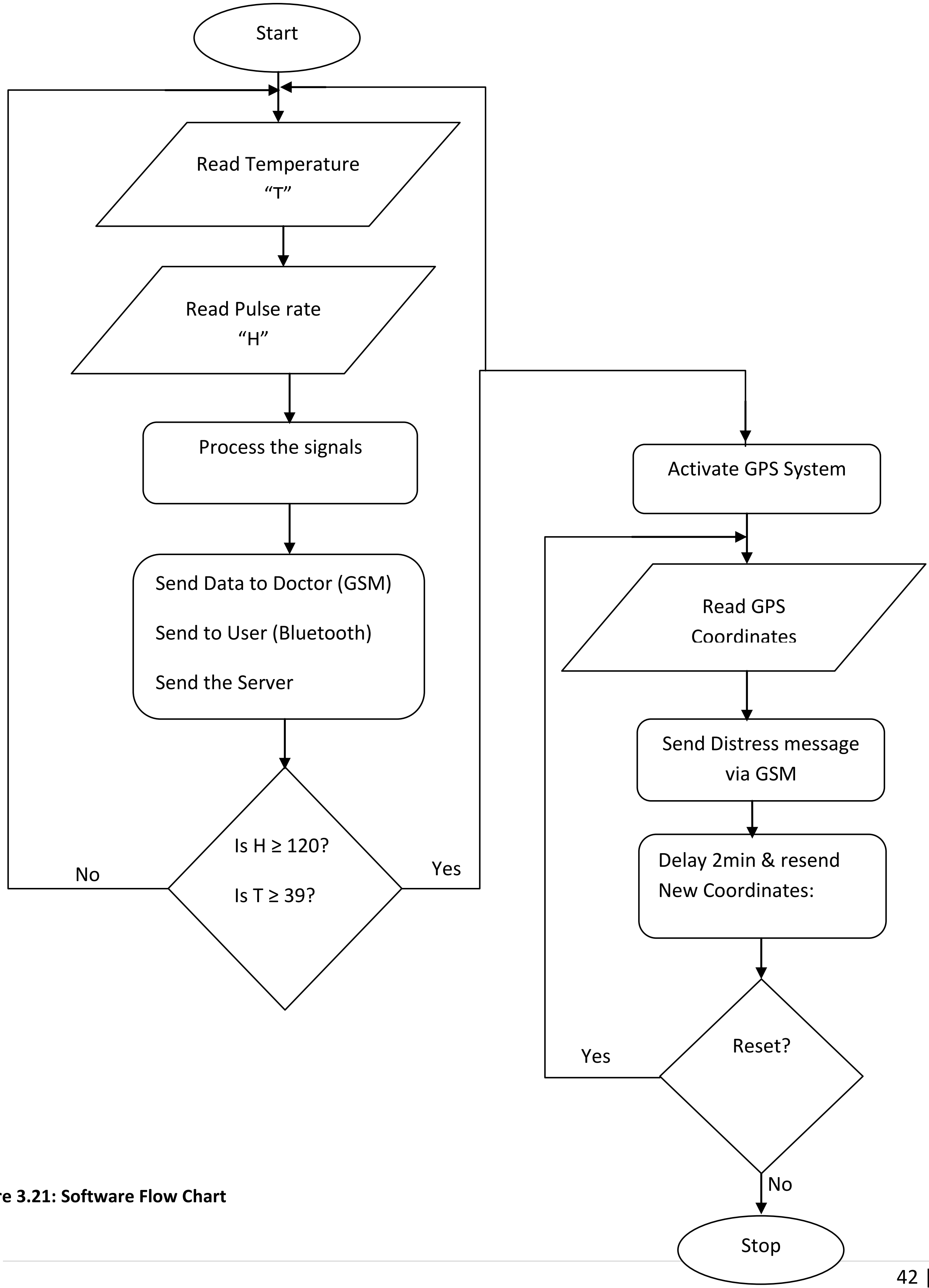


Figure 3.21: Software Flow Chart

3.8 Testing

Three experiments were conducted;

a) To determine the response of Signal acquisition system when the circuit is powered

b) To Test and verify transmission of data via Bluetooth, SMS, and WIFI

c) To verify transmission of emergency signal and message to the emergency operators

The experiment set up was as shown in the snapshots below;

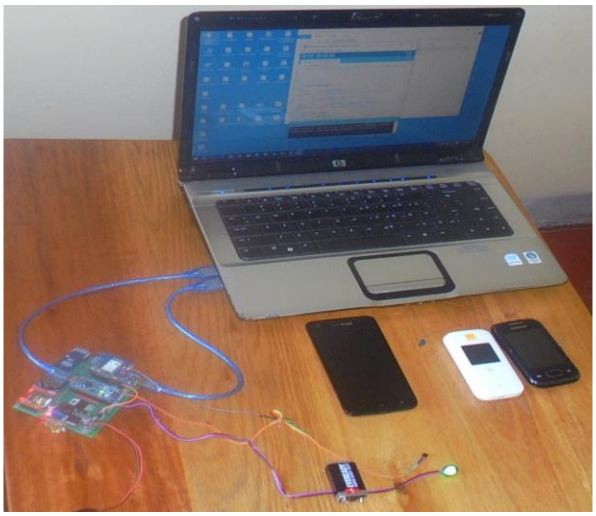


Figure 3.22: Experiment 1

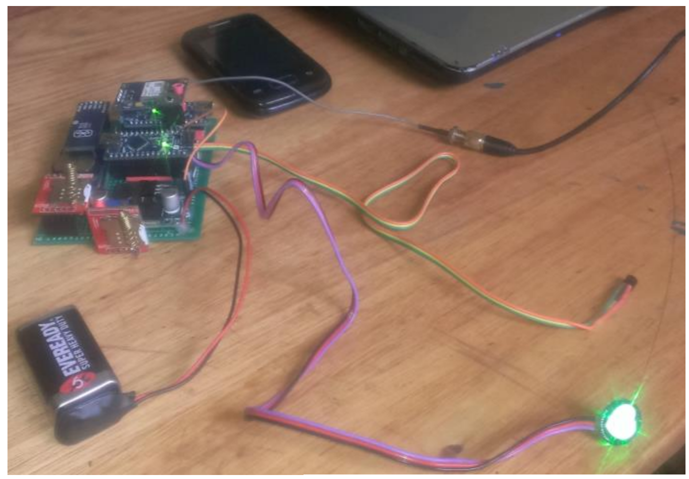


Figure 3.23: Experiment 2

3.8.1 Signal Acquisition System

Set up in figures 3.22 and 3.23 were used to test the response in signal acquisition and transmissions respectively. The Arduino software application was opened and the procedure shown below was followed.

Step 1: Open the Arduino software

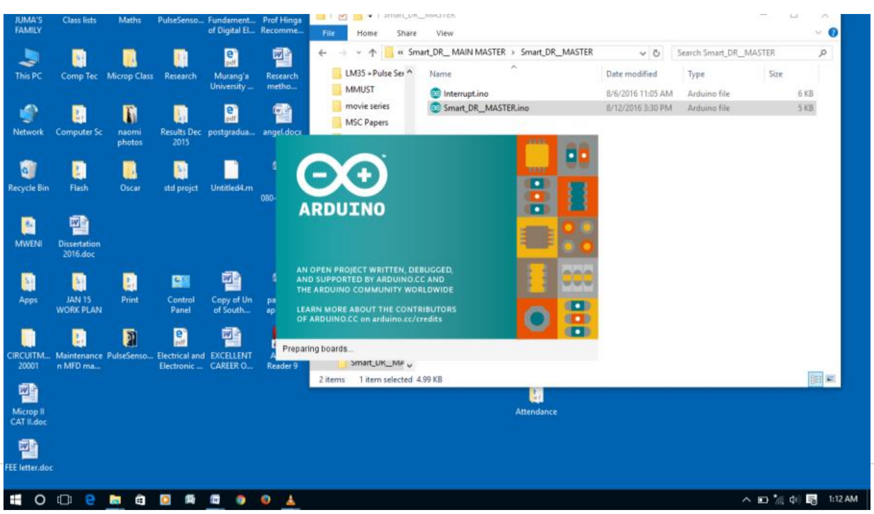


Figure 3.24: Opening Arduino Software Platform

Step 2; Verify code

With the set up as in figure 4.25 click on the verify the code and the communication ports on which the Microcontroller board is connected as indicated in figure 4.26.

Figure 3.25: Verifying the Code

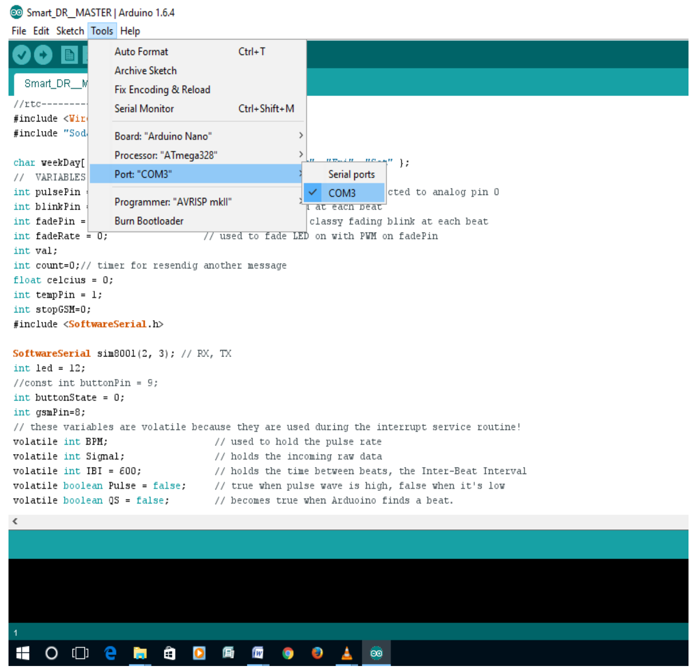


Figure 3.26: Connecting the Board to the Serial port

The code is provided in appendices I, II and III

Step 3 Run the system

Open the Serial port monitor and observe the results from the sensors. Sample results are shown in the figure 3.27 and 3.28.

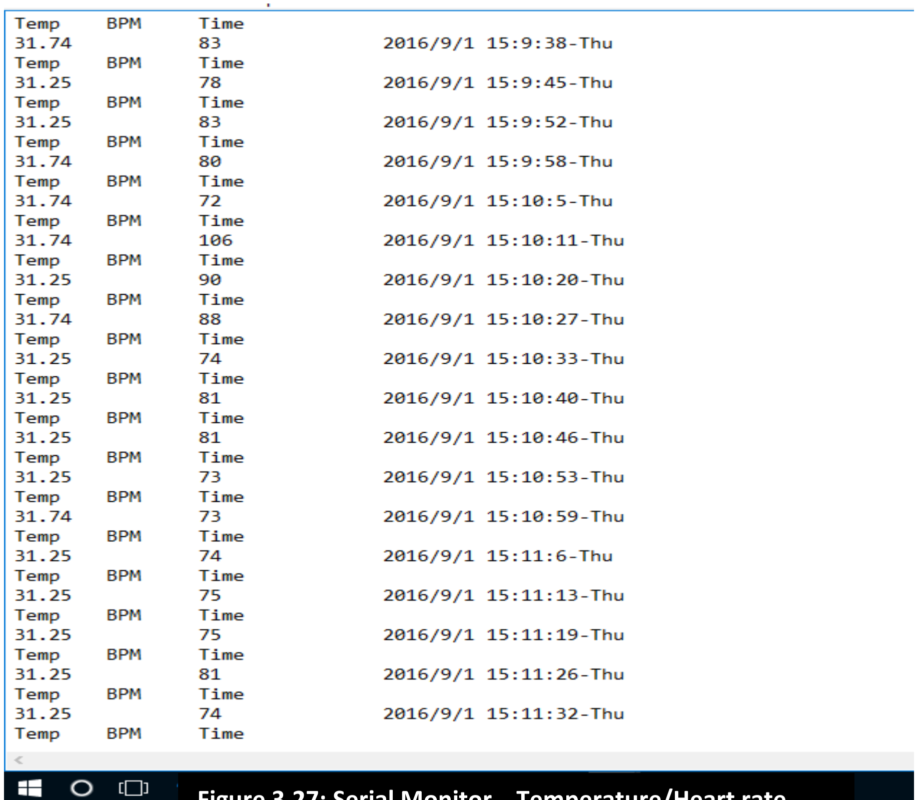


Figure 3.27: Serial Monitor Temperature/Heart rate

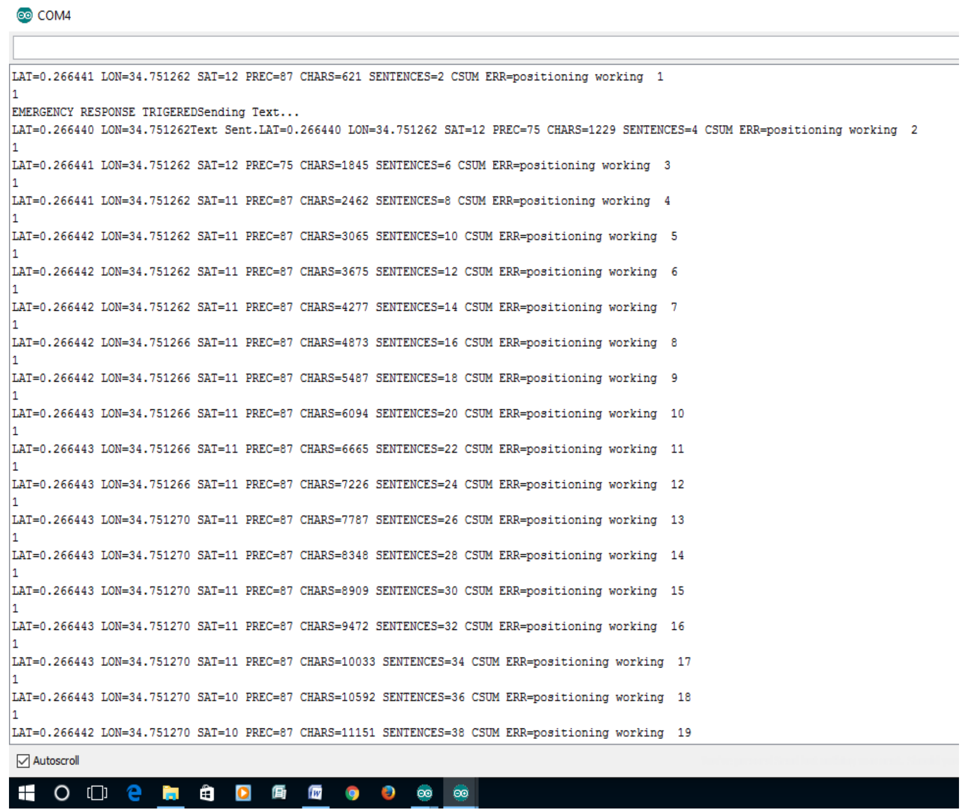


Figure 3.28: Serial Monitor GPS Results

3.8.2 GSM and Bluetooth transmission tests

The device periodically sends messages to a designated mobile phone via GSM-SMS service and Bluetooth. It was verified that the system transmitted data acquire as seen in the test snapshots in figures 3.29 and 3.30 below.

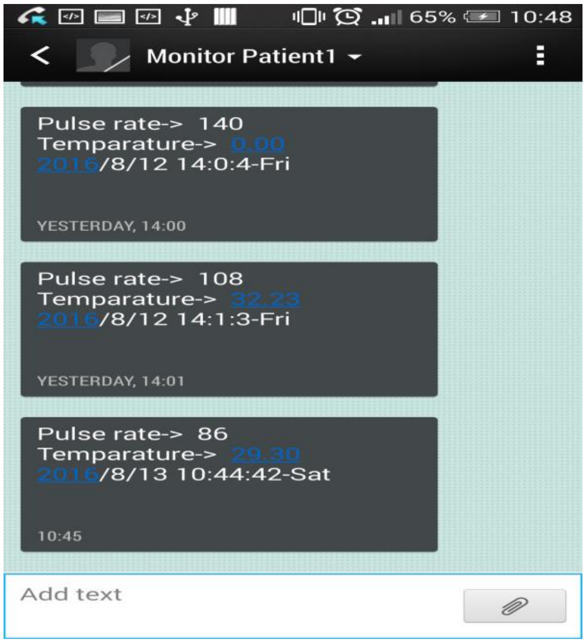


Figure 3.29: GSM-SMS Sample Data

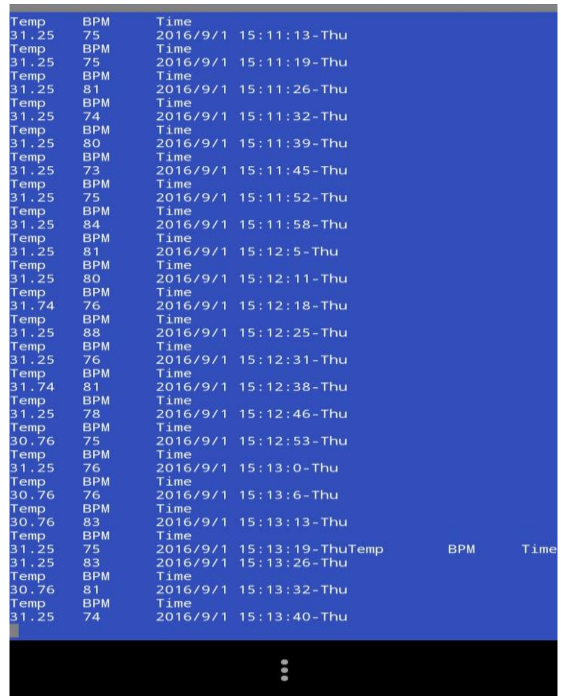


Figure 3.30: Bluetooth sample Data

3.8.3 Emergency Messaging.

The emergency messaging system was tested and it was verified that it worked correctly as expected.

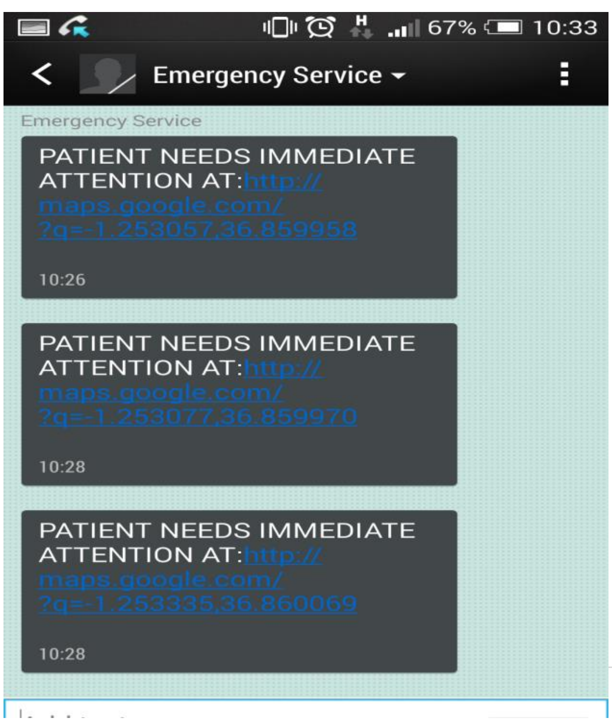


Figure 3.31: Sample Emergency Alert Message

3.8.4 Connecting to the web Server.

In order for the results to be send and displayed on a web site, the system was linked to thingspeak.com web server, a site that supports Internet of Things (IoT) developers to post and manipulate their data for visualization. The process involved registration and acquisition of an API key to be used in the program.

Step 1: Open the thingSpeak website through URL; www.thingspeak.com/ .

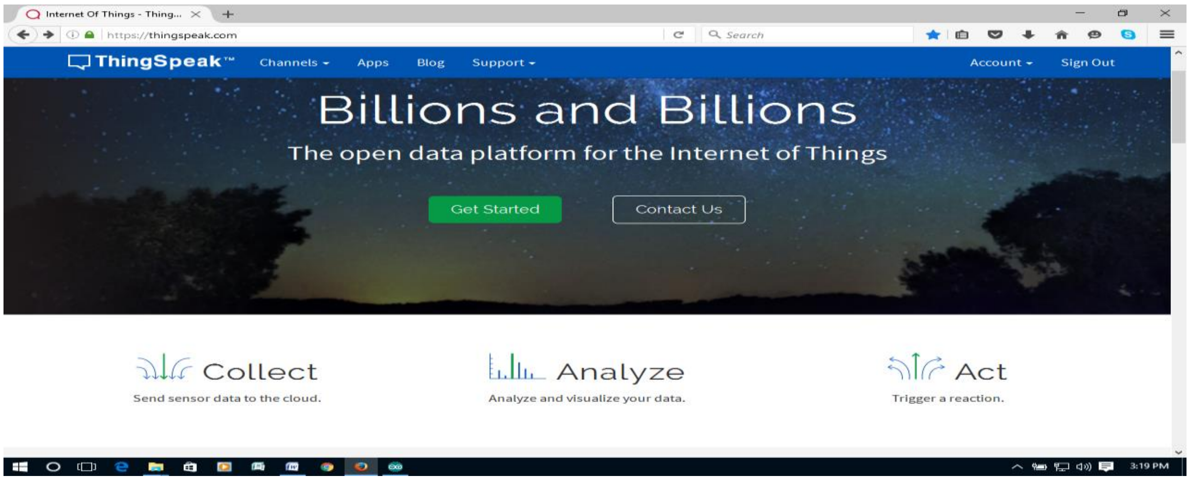


Figure 3.32: ThingSpeak Website

Step 2: Register a new channel, with details of the variables you intend to monitor.

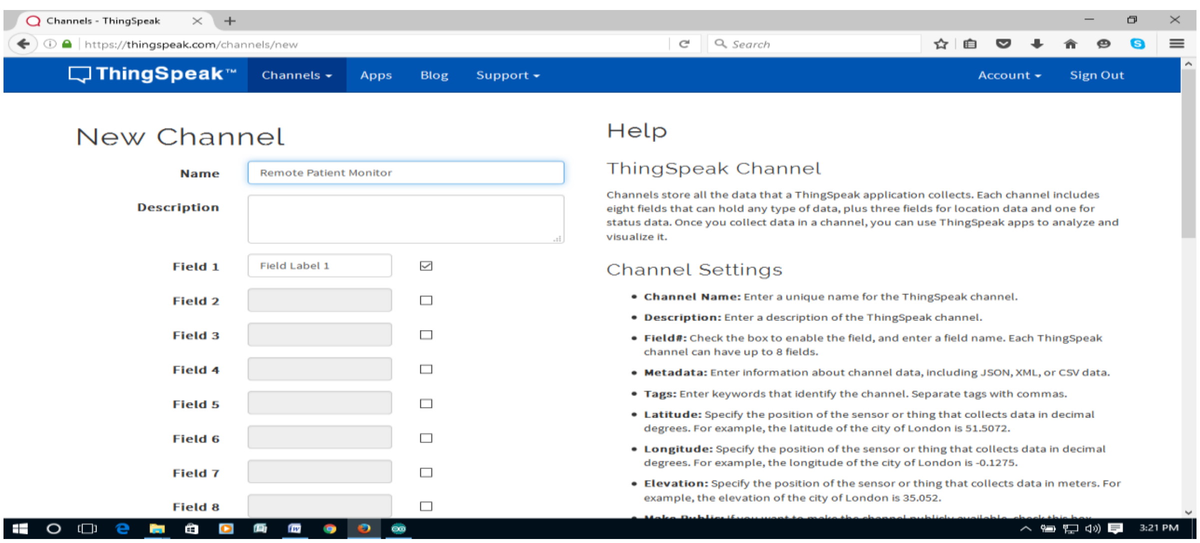


Figure 3.33: ThingSpeak Channel Creation

Step 3: Obtain the API key (Application Programming Interface Key) as directed by the procedure provided on the website.

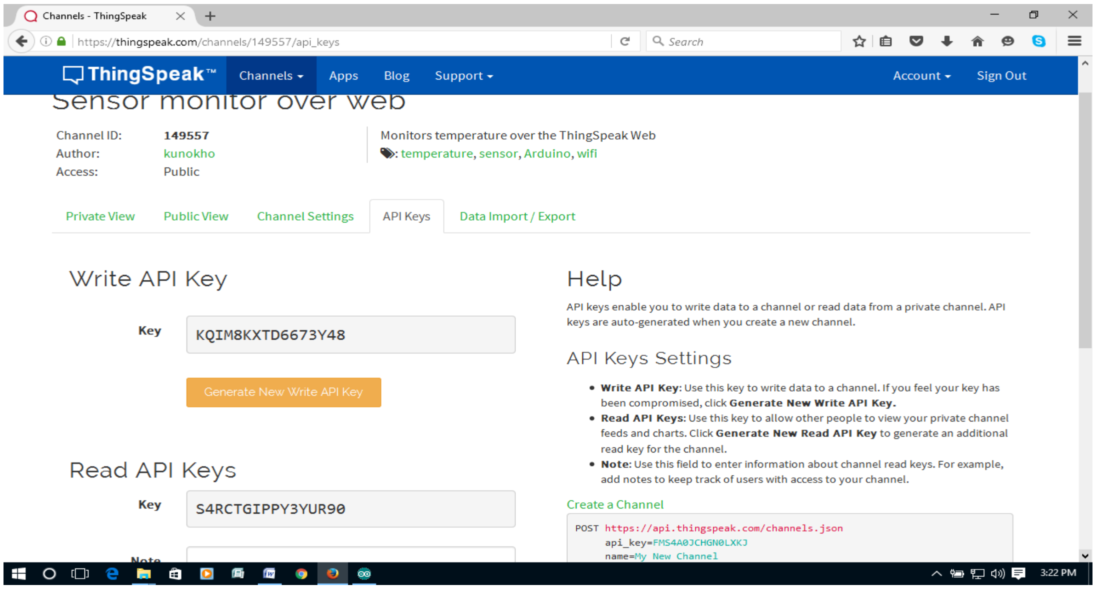


Figure 3.34: API Key

Step 4: Appropriately insert the key in the code of your application so as to link your program to the website.

CHAPTER FOUR

4.0 Results and Discussion

Generally a delay of five seconds was set between subsequent transmissions. Data was send via the Bluetooth, GSM and the WIFI.

4.1 Serial Monitor

The Arduino IDE provides a feature that enables the programmer run the sketches to view the output of the microcontroller thus enabling him to debug or control the Arduino from the computer keyboard. In this research project the serial monitor was used to view the data being generated by the microcontroller and sent to the remote recipients.

Part of the data observed and captured is as shown in figures 3.27 and 3.28. This verified that the system was working correctly and therefore the researcher can go ahead and verify the transmissions through the various modes namely; Bluetooth, GSM, and WIFI

4.2 Bluetooth Transmission

Data via Bluetooth module was received and displayed by a specially created Mobile App to read and display data inform of text. The app has a data logging feature and therefore historical data can be accessed by the caregiver or the user at later a date.

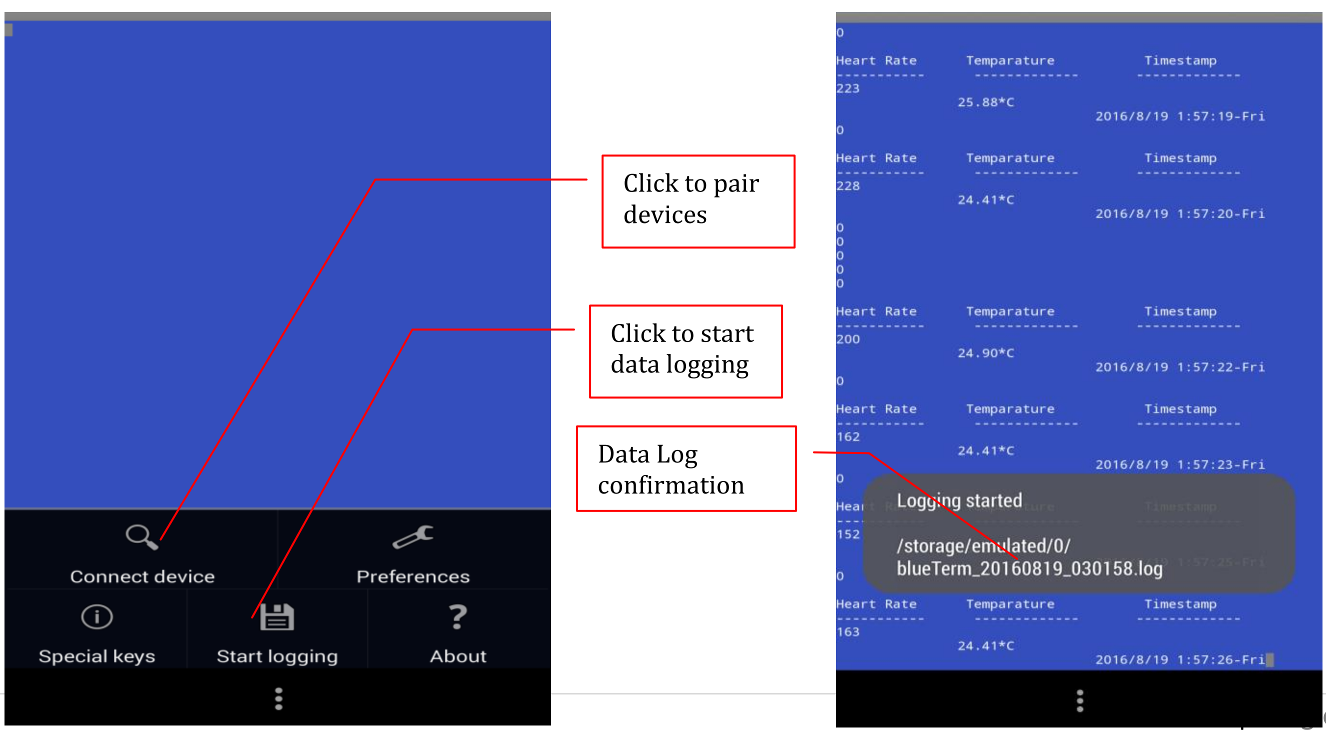


Figure 4.1: Bluetooth App Features

Figure 4.2: Bluetooth App. Data Logging

In Figure 4.1, the data logger is activated by clicking on the start logging button. Figure 4.2 shows confirmation message that the data received is being saved in the named file.

Figure 4.3 below shows how data in the mobile phone was accessed by connecting the phone on a computer.

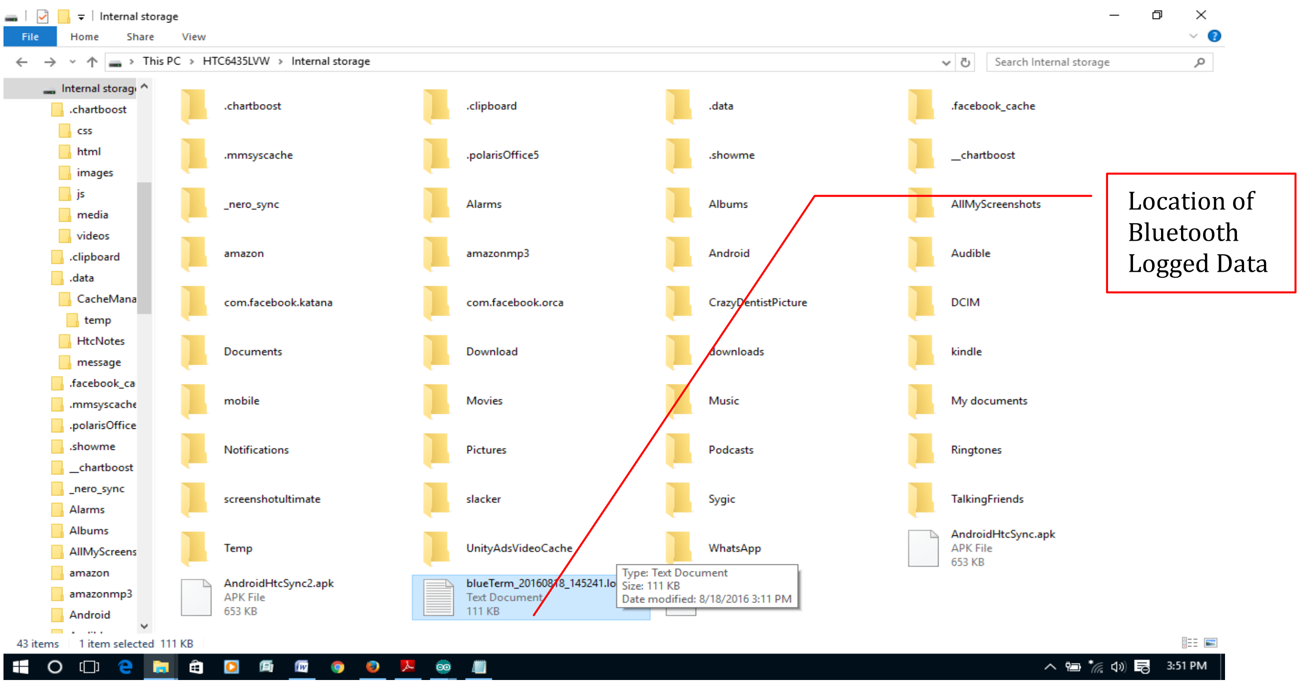
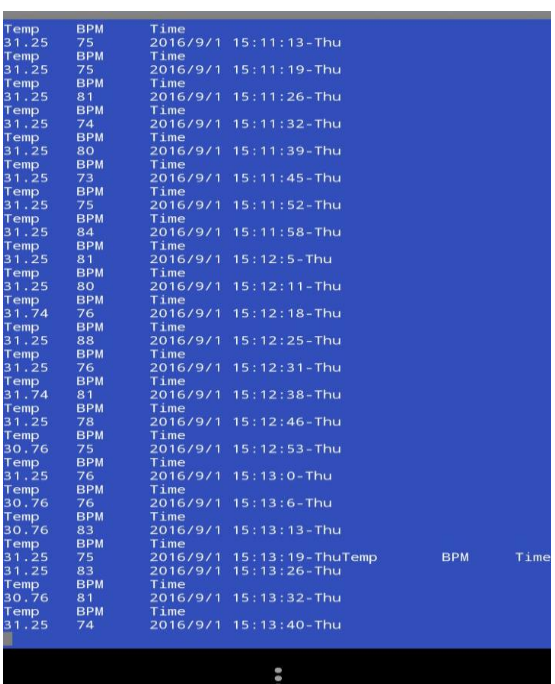


Figure 4.3: Access to Bluetooth Logged Data

4.1.1 Bluetooth Output

The data logging system worked well and sample data as observed on the user app and data logger is as shown in the figures 4.4 and 4.5 respectively



```
Temp   BPM   Time
31.25  75    2016/9/1 15:11:13-Thu
Temp   BPM   Time
31.25  75    2016/9/1 15:11:19-Thu
Temp   BPM   Time
31.25  81    2016/9/1 15:11:26-Thu
Temp   BPM   Time
31.25  74    2016/9/1 15:11:32-Thu
Temp   BPM   Time
31.25  80    2016/9/1 15:11:39-Thu
Temp   BPM   Time
31.25  73    2016/9/1 15:11:45-Thu
Temp   BPM   Time
31.25  75    2016/9/1 15:11:52-Thu
Temp   BPM   Time
31.25  84    2016/9/1 15:11:58-Thu
Temp   BPM   Time
31.25  81    2016/9/1 15:12:5-Thu
Temp   BPM   Time
31.25  80    2016/9/1 15:12:11-Thu
Temp   BPM   Time
31.74  76    2016/9/1 15:12:18-Thu
Temp   BPM   Time
31.25  88    2016/9/1 15:12:25-Thu
Temp   BPM   Time
31.25  76    2016/9/1 15:12:31-Thu
Temp   BPM   Time
31.74  81    2016/9/1 15:12:38-Thu
Temp   BPM   Time
31.25  78    2016/9/1 15:12:46-Thu
Temp   BPM   Time
30.76  75    2016/9/1 15:12:53-Thu
Temp   BPM   Time
31.25  76    2016/9/1 15:13:0-Thu
Temp   BPM   Time
30.76  76    2016/9/1 15:13:6-Thu
Temp   BPM   Time
30.76  83    2016/9/1 15:13:13-Thu
Temp   BPM   Time
31.25  75    2016/9/1 15:13:19-ThuTemp     BPM     Time
31.25  83    2016/9/1 15:13:26-Thu
Temp   BPM   Time
30.76  81    2016/9/1 15:13:32-Thu
Temp   BPM   Time
31.25  74    2016/9/1 15:13:40-Thu
```

Figure 4.4: Bluetooth App Data – User Interface

blueTerm_20160901_150917.log - Notepad

File Edit Format View Help

```
Temp   BPM   Time
31.74  71          2016/9/1 15:9:9-Thu
Temp   BPM   Time
31.74  81          2016/9/1 15:9:15-Thu
Temp   BPM   Time
31.74  78          2016/9/1 15:9:23-Thu
Temp   BPM   Time
31.74  81          2016/9/1 15:9:30-Thu
Temp   BPM   Time
31.74  83          2016/9/1 15:9:38-Thu
Temp   BPM   Time
31.25  78          2016/9/1 15:9:45-Thu
Temp   BPM   Time
31.25  83          2016/9/1 15:9:52-Thu
Temp   BPM   Time
31.74  80          2016/9/1 15:9:58-Thu
Temp   BPM   Time
31.74  72          2016/9/1 15:10:5-Thu
Temp   BPM   Time
31.74  106         2016/9/1 15:10:11-Thu
Temp   BPM   Time
31.25  90          2016/9/1 15:10:20-Thu
Temp   BPM   Time
31.74  88          2016/9/1 15:10:27-Thu
Temp   BPM   Time
31.25  74          2016/9/1 15:10:33-Thu
Temp   BPM   Time
31.25  81          2016/9/1 15:10:40-Thu
Temp   BPM   Time
31.25  81          2016/9/1 15:10:46-Thu
Temp   BPM   Time
31.25  73          2016/9/1 15:10:53-Thu
Temp   BPM   Time
31.74  73          2016/9/1 15:10:59-Thu
Temp   BPM   Time
31.25  74          2016/9/1 15:11:6-Thu
Temp   BPM   Time
```

Figure 4.5: Bluetooth Logged Data

Though taken at different times as seen in the figures above the values indicate the temperature, heart rate and time at which the signals were acquired.

4.3 GSM Transmission

4.3.1 Regular data transmissions for Patient monitoring

The short message service of the system worked well and part of the data received is as shown in figure 4.6. A mobile App to specifically receive and display data from the Arduino based remote health monitoring system was developed. A sample is as shown in figure 4.7

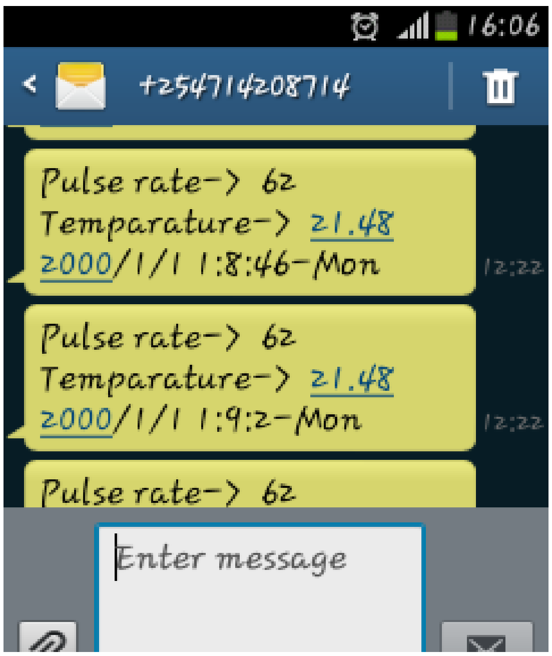


Figure 4.6: Sample data on Normal SMS format

Figure 4.7: Sample Data on SMS App.

4.3.2 Distress Messages

The threshold values for the heart rate and temperature were set at 80 and 39^{0}C. For purposes of this research a heating element was used to trigger high temperature values. High values triggered the alert system that sends an alert message with GPS coordinates for easy location of the patient by the ambulance service providers or any emergency service operatives. Sample texts are shown in figure 4.8. To get the exact location one has to click on the Google map link in the text message. Sample location from one of the messages is as shown in figure 4.9

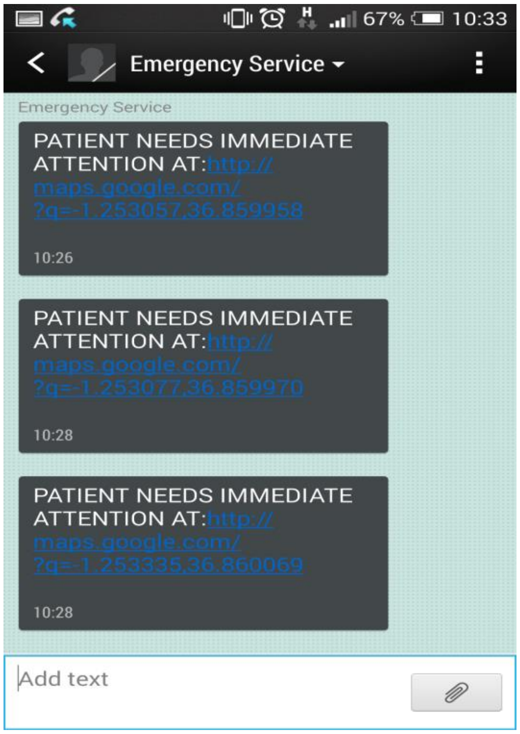


Figure 4.8: Sample Alert Message with Coordinates

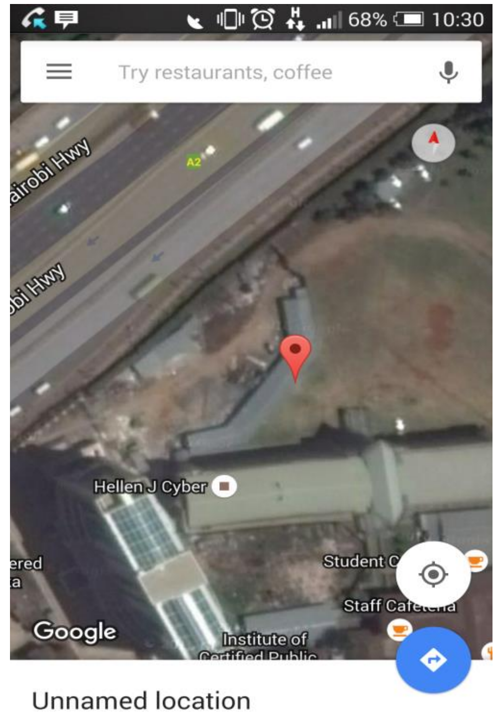


Figure 4.9: Google Map Reading from GPS Coordinates

4.4 WIFI to the Web server results

A WIFI module ESP8266 was used to enable transmission of data to the web server. The website, thingspeak.com was used in this research. Both line graph and bar graph modes were applied to display the data from the Arduino based health monitoring system. Sample data is as shown in figures 4.10 and 4.11

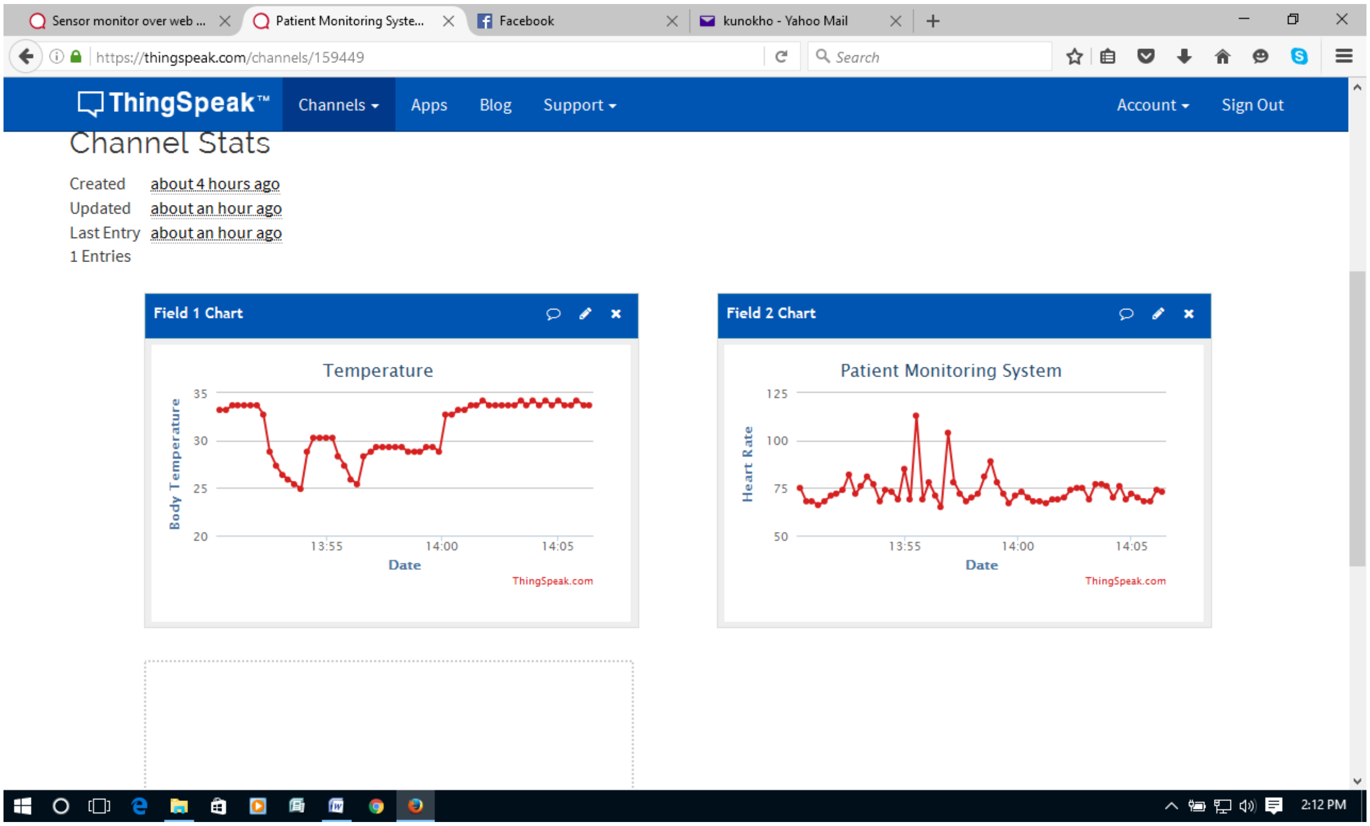


Figure 4.10: Sample Thingspeak web server Data in Line graph

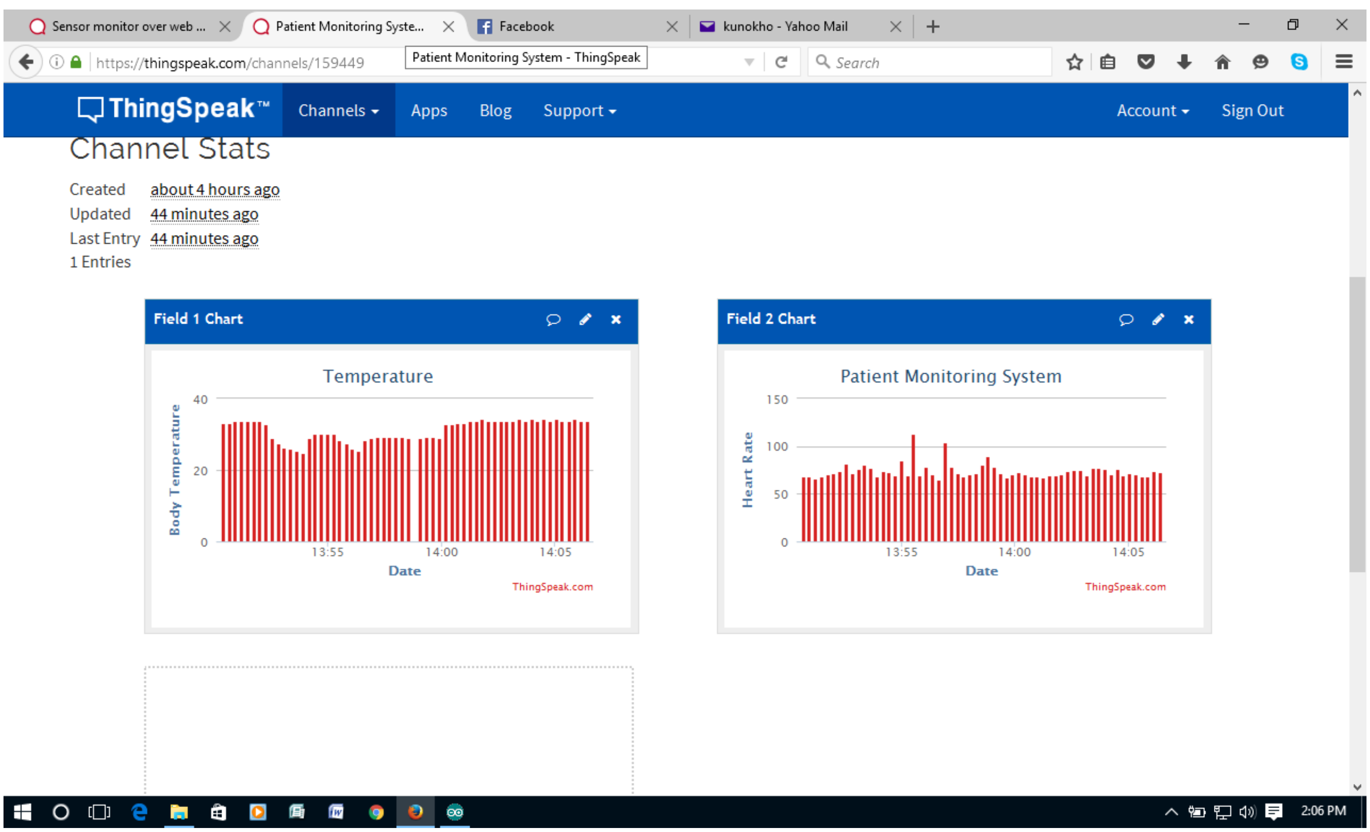


Figure 4.11: Sample Thingspeak Web server Data in Bar graph Format

4.5 Evaluation of the results

4.5.1 Bluetooth transmission

A maximum distance of 7 metres between transmitting device and the receiving phone was used for this research. The operation of the system was not hindered by movements within the stated radius. A 100% data transmission and reception was recorded.

4.5.2 GSM transmission

The module transmitted temperature and heart rates as expected. It was noted that when the spacing of message transmission is small, in terms of seconds, there is a delay in the phone reception. For instance when the transmission setup was in the intervals of two seconds, the messages clog up and the delay could go up to 10 seconds especially when the system sends many messages. When this is the case the phone kept on receiving messages up to an average of 30 seconds after the last data was send from the monitoring system.

There was no noticeable delay experienced when the interval was increased to the minutes range. However note that we didn't carry out tests on performance under harsh conditions like cases where we have many subscribers sending messages over the network. A good example is during Christmas or New Year celebrations where we have many people sending messages at the same time.

In the case of alert signal transmission, the output is as shown in figure 4.8. The response of the system was a success, however it was observed that the first coordinates send by the GPS were inaccurate with an average deviation of 62 feet, approximately 19 metres, (see figures 4.12 and 4.13)

The deviation can be attributed to the fact that the second setup of the system is designed in such a manner that it is only activated when the threshold values are surpassed, otherwise it remains in sleep mode.

On 'wakeup', the GPS is slow in picking accurate coordinates instantly as it scans for the right GPS satellites.

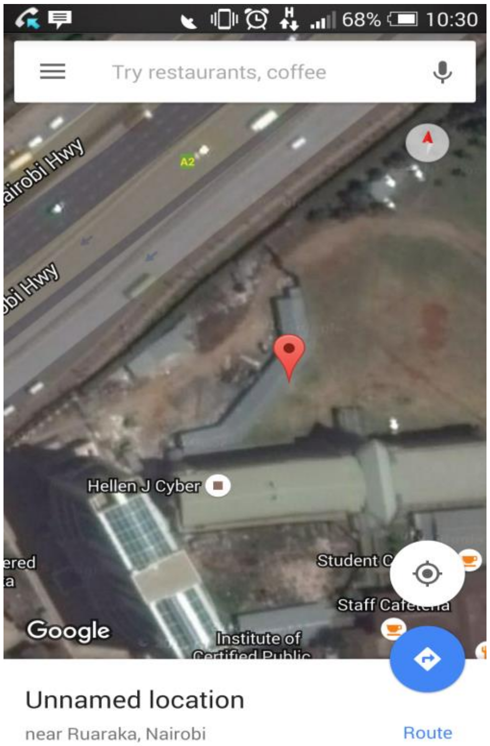


Figure 4.12: Deviation Measurement

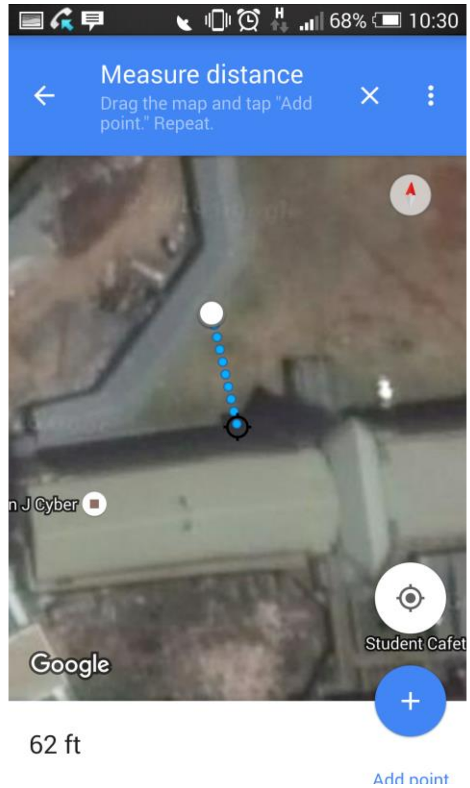


Figure 4.13: Results from Third GPS reading

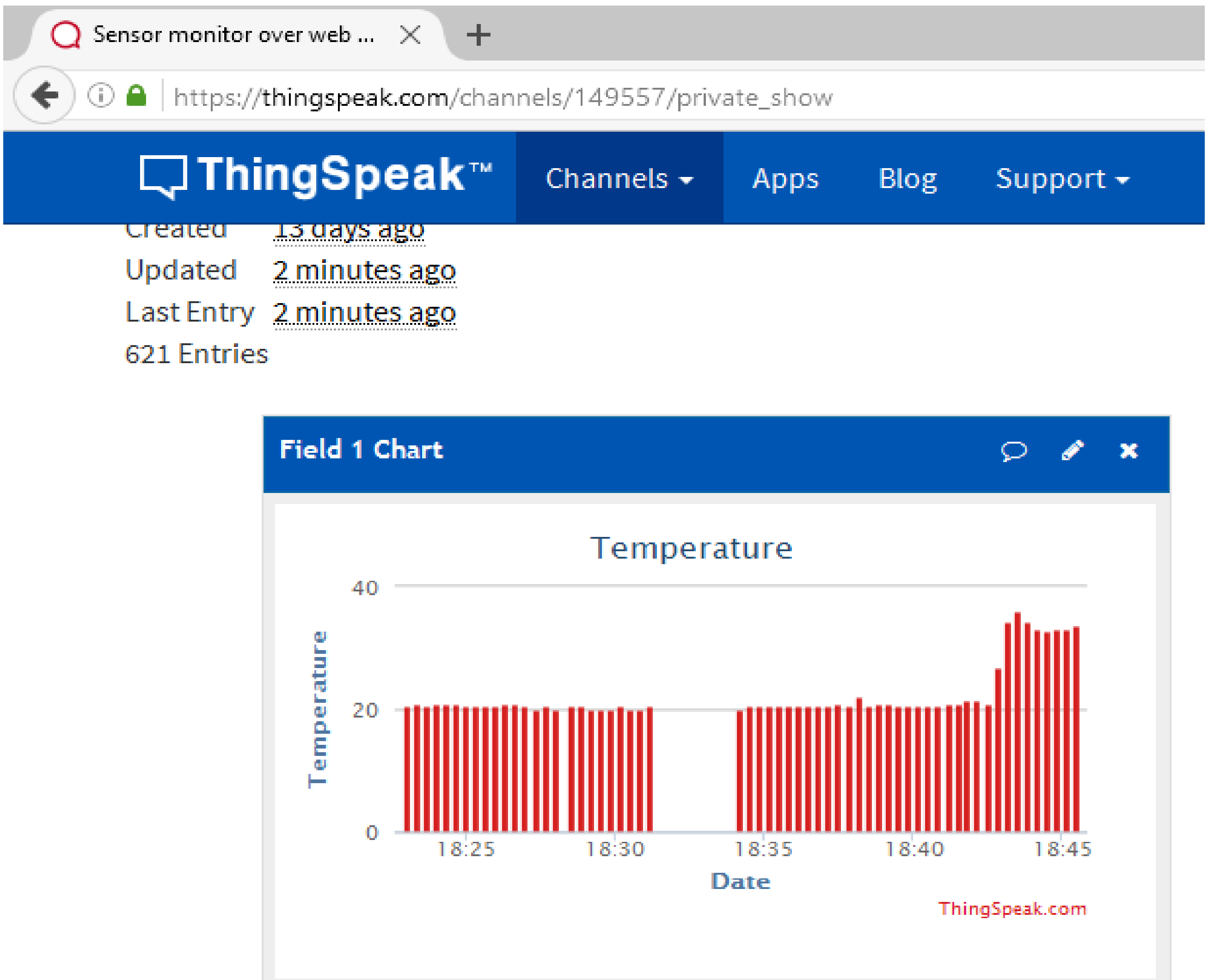
The second and third readings give almost accurate positioning as seen in figure 4.14.

Figure 4.14: Results from Third GPS reading

4.5.3 Web Server Results

The device was able to send data to the web server as expected. The data was send at an interval of five seconds however the thingSpeak website updated after every fifteen seconds.

Temperature Sensor Results



Figur
e 4.15: Temperature Sensor Results

As seen from the graph in figure 4.15 above, the temperature sensor worked as expected. At the start the sensor is at 'resting state' i.e. indicating room temperature. When the sensor is held in the hand or placed on the body the temperature starts rising steadily up the maximum, which is the body temperature of the patient. When released the readings start to go back to the room temperature.

Pulse Sensor

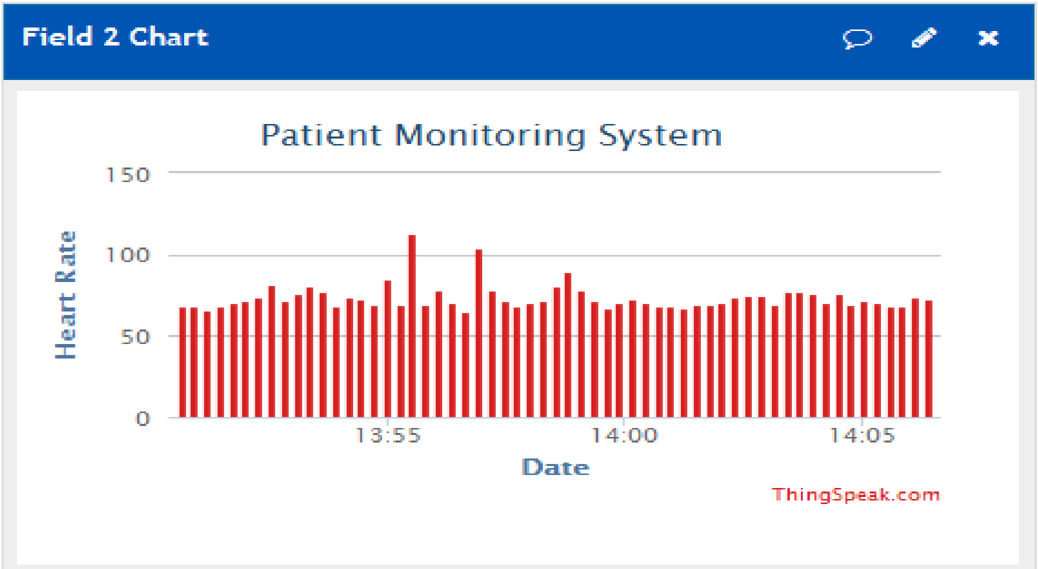


Figure 4.16: Pulse Sensor Readings

Heart rate readings as received from the pulse sensor are as shown in figure 4.16 above. The Heart rate sensor worked as expected with only a few hitches experienced as a result of sensitivity of the sensor to body movements. With less movement, better output was obtained just as seen in figures 4.10 and 4.16.

Summary of the system performance is provided in the tables below

Table 4.1: System Performance Summary

ITEM	Function	Priority	Remarks
GSM 1	Data Transmission	Normal	Worked as expected
GSM 2	Data Transmission	Urgent/High	Worked as expected
Bluetooth	Data Transmission	Normal	Worked as expected
WIFI	Data Transmission	Normal	Worked as expected
Temperature Sensor	Sense body Temperature	High	Worked as expected
Pulse Sensor	Heart Rate signal	High	Worked well though sensitive to external interference

Generally the transmission of data via the various modes was satisfactory. The temperature sensor data were stable and as per the expectations of the researcher, however there were challenges working with the pulse sensor.

A more rugged sensor or signal stabilization circuit may be required for implementation of the system in case where the patient is involved in a lot of movement.

CHAPTER FIVE

5.0 Recommendation and Conclusion

5.1 Conclusion

A simple prototype of remote health monitoring system was developed using pulse and temperature sensors which was capable of transmitting data through WIFI, GSM-SMS and Bluetooth.

The System was able to transmit data to a web server through the ESP8266 WIFI module. It was also able to send data to a mobile phone via SMS and relayed an alert message with GPS coordinates when threshold values were exceeded. It also successfully sends data to the patient's smart phone through a Bluetooth module.

In general the proposed system was a success because each of the system criteria was achieved, just as demonstrated in the previous sections.

5.2 Recommendation

In this research only two sensors were used to demonstrate that it is possible to transmit data from remote places through various communication channels available. Previous research has shown that it is possible to have a number of physiological sensors in one wearable health monitoring device.

To avoid a case of large and bulky wearable device, mobile applications can be used to wirelessly receive, interpret and analyze the data from physiological sensors and issue an alert when certain factors are not met.

Thingspeak web server was used in this research to have data displayed on a website. A system can be designed that has data analytic capabilities specifically for wireless medical devices so that the data received can be used to predict events, and their causes. This will help medical practitioners to act before catastrophic events occur.

Wireless devices need to be powered to operate well without fail. One of the challenges in remote wireless transmission of data is continuous source of power supply to the devices. More research need to be done on low power sensor technologies and alternative sources so as to realize the dream of remote health monitoring of patients especially in areas with no electricity supply.

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APPENDIX I: Data Transmission Code for Arduino U1

Includes; instructions that control WIFI, GSM 1and Bluetooth as well as data acquisition from Temperature Sensor and RTC Modules.

```
#include <Wire.h>
#include "Sodaq_DS3231.h"
#include <SoftwareSerial.h>

SoftwareSerial sim800l(2, 3); // RX, TX
SoftwareSerial bluetooth(10, 11); // RX, TX

#define tempPin 1
#define gsmPin 8
#define ssid "uFi_452093"
#define pass "RG754H4J6G"
String apikey = "KQIM8KXTD6673Y48";
String url = "api.thingspeak.com";

boolean getRequest(String IP, String request, int port=80); // declaration of procedure

char weekDay[][4] = {"Sun", "Mon", "Tue", "Wed", "Thu", "Fri", "Sat" };
boolean gsm = true;              // determines whether gsm module is used or not
int timeInterval = 5000;         // time interval between sending data
long prevTime = 0;               // previous time data was sent
String BPM = "";                 // used to hold the pulse rate
float temperature = 0;           // holds temperature value

void setup() {
  //initialize RTC clock communication
  Wire.begin();
  rtc.begin();
  // set baud rates for the different serial ports
  bluetooth.begin(9600);
  sim800l.begin(4800);
  Serial.begin(9600);

  //connect to hotspot. If not successful start gsm module serial port
  if (connectWiFi()){
    //Serial.println("Success!!");
    gsm = false; // GSM module will not be used
  }
  else if (!connectWiFi()){
    //Serial.println("Did not connect to hotspot!!");
    gsm = true; // GSM module will be used
  }

  pinMode(gsmPin, OUTPUT);
  delay(1000);
}

void loop() {
  bluetooth.listen();
  if(bluetooth.available()){
    String command = bluetooth.readString();
    BPM = command; //.substring(command.indexOf("B")+1, command.indexOf("\n")); // get BPM
  }
```

```
  //get temp data
  float val = (analogRead(tempPin));
  temperature = float(val*5000)/1024;
  temperature = float(temperature)/10;

  if((millis() - prevTime) > timeInterval){
    bluetooth.listen();
    //Serial.println("Bluetooth sending");
    sendBluetooth(); //send data to bluetooth module
    delay(1000);
    sendToServer(); // update thinkspeak
    delay(1000);
    sim800l.listen();
    sendAlert(); // send sms
    prevTime = millis();
  }

  int i = stringtoInt(BPM);
  //patient in a critical condition-send gps location to the doctor
  if ((i > 120)||(temperature>39)){
    digitalWrite(gsmPin,HIGH);
  }
  else{
    digitalWrite(gsmPin,LOW);
  }

  delay(20);
}

void sendToServer(){
  String temp = String(temperature);
  //build GET request
  String GET = "/update?api_key="+apikey+"&field1="+temp+"&field2="+BPM;

  if (getRequest(url, GET, 80)){}//bluetooth.println("Data sent"); // get request successfully sent
  //else bluetooth.println("Error! Data not sent"); // get request failed
}


/*
 * handle the get request and send it to server
 */
boolean getRequest(String IP, String request, int port){
  String atTcpPortConnectCmd = "AT+CIPSTART=\"TCP\",\""+IP+"\","+port+""; // TCP connection command
  sendData(atTcpPortConnectCmd); // sent TCP commands
  delay(2000);
  if( Serial.find("Error") ){ // did not send successfully
    //bluetooth.print( "RECEIVED: Error\nExit1" );
    return false;
  }

  String atHttpGetCmd = "GET /"+request+" HTTP/1.0\r\n\r\n"; // get request
  int len = atHttpGetCmd.length();
  String atSendCmd = "AT+CIPSEND=";
  atSendCmd+=len;
  sendData(atSendCmd);
  if(Serial.find( ">" )) { // CIPSEND command successfully sent
    //bluetooth.print(">");
    //bluetooth.print(atHttpGetCmd);
```

```
    Serial.print(atHttpGetCmd); // send get request
  }
  else { // close TCP connection if there CIPSEND not successfully sent
    sendData( "AT+CIPCLOSE" );//close TCP connection
  }
  if( Serial.find("OK")){ // successfully sent get request
    //bluetooth.println( "RECEIVED: OK" );
    return true;
  }
  else{ // get request failed
    //bluetooth.println( "RECEIVED: Error\nExit2" );
    return false;
  }
}

/*
 * Connect to wifi hotspot
 */
boolean connectWiFi(){
  Serial.println("AT+CWMODE=1");//WiFi STA mode - if '3' it is both client and AP
  delay(2000);

  String cmd = "AT+CWQAP";
  sendData(cmd); // disconnect from any connected hotspots
  delay(2000);
  //Connect to Router with AT+CWJAP="SSID","Password";
  // Check if connected with AT+CWJAP?
  cmd="AT+CWJAP=\"";
  cmd+=ssid;
  cmd+="\",\"";
  cmd+=pass;
  cmd+="\"";
  sendData(cmd);
  delay(5000);
  if(Serial.available()){ // connected
    //bluetooth.println("RECEIVED: OK");
    String s = Serial.readString();
    if(s.indexOf("OK") != -1)return true;
    else return false;
  }

  cmd = "AT+CIPMUX=0";// Set Single connection
  sendData( cmd );
  if( Serial.find( "Error")){
    //bluetooth.print( "RECEIVED: Error" );
    return false;
  }
}

/*
 * Sends data to esp8266 and bluetooth serial port - softwareSerial 10,11
 */
void sendData(String command){
  Serial.println(command);
  //bluetooth.println(command);
}


void sendAlert(){
```

```
  //Serial.println("Sending Text...");
  sim800l.print("AT+CMGF=1\r"); // Set the shield to SMS mode
  delay(100);
  sim800l.print("AT+CMGS=\"+254720288370\"\r");//start with Kenya call code +254----------
  delay(100);
  sim800l.print ("Pulse rate->  ");//the content of the message
  sim800l.print (BPM);//the content of the message
  sim800l.print ("             Temparature->  ");//the content of the message
  sim800l.print (  temperature);//the content of the message

  delay(1000);
  sim800l.print ("      ");

  DateTime now = rtc.now(); //get the current date-time
  sim800l.print(now.year(), DEC);
  sim800l.print('/');
  sim800l.print(now.month(), DEC);
  sim800l.print('/');
  sim800l.print(now.date(), DEC);
  sim800l.print(' ');
  sim800l.print(now.hour(), DEC);
  sim800l.print(':');
  sim800l.print(now.minute(), DEC);
  sim800l.print(':');
  sim800l.print(now.second(), DEC);
  sim800l.print('-');
  sim800l.print(weekDay[now.dayOfWeek()]);
  sim800l.println();
  delay(1000);
  sim800l.print("\r");
  sim800l.print((char)26);//the ASCII code of the ctrl+z is 26 (required according to the datasheet)
  sim800l.println();
  delay(2000);
}

void sendBluetooth(){
  bluetooth.print("Temp");bluetooth.print("\t");bluetooth.print("BPM");bluetooth.print("\t");bluetooth.println("Time"); // send
data via bluetooth
  bluetooth.print(temperature);bluetooth.print("\t\t");bluetooth.print(BPM);bluetooth.print("\t\t");// send data via bluetooth
  DateTime now = rtc.now(); //get the current date-time
  bluetooth.print(now.year(), DEC);
  bluetooth.print('/');
  bluetooth.print(now.month(), DEC);
  bluetooth.print('/');
  bluetooth.print(now.date(), DEC);
  bluetooth.print(' ');
  bluetooth.print(now.hour(), DEC);
  bluetooth.print(':');
  bluetooth.print(now.minute(), DEC);
  bluetooth.print(':');
  bluetooth.print(now.second(), DEC);
  bluetooth.print('-');
  bluetooth.print(weekDay[now.dayOfWeek()]);
  bluetooth.println();
  delay(1000);
}

void CLOCK (){
  DateTime now = rtc.now(); //get the current date-time
```

```
  Serial.print ("                              ");
  Serial.print(now.year(), DEC);
  Serial.print('/');
  Serial.print(now.month(), DEC);
  Serial.print('/');
  Serial.print(now.date(), DEC);
  Serial.print(' ');
  Serial.print(now.hour(), DEC);
  Serial.print(':');
  Serial.print(now.minute(), DEC);
  Serial.print(':');
  Serial.print(now.second(), DEC);
  Serial.print('-');
  Serial.print(weekDay[now.dayOfWeek()]);
  Serial.println();
  delay(1000);
}

// convert from string to int
int stringtoInt(String buff){
  int r = 0;
  for (uint8_t i = 0; i < buff.length(); i++){
   r = (r*10) + (buff[i] - '0');
  }
  return r;
}
```

APPENDIX II: Pulse Sensor Code for Arduino U3

Main Code;

```
//  VARIABLES
int pulsePin = 0;                // Pulse Sensor purple wire connected to analog pin 0
int blinkPin = 13;               // pin to blink led at each beat
int fadePin = 5;                 // pin to do fancy classy fading blink at each beat
int fadeRate = 0;                // used to fade LED on with PWM on fadePin
int timeInterval = 5000;         // time interval between sending data
long prevTime = 0;               // previous time data was sent

// these variables are volatile because they are used during the interrupt service routine!
volatile int BPM;                   // used to hold the pulse rate
volatile int Signal;                // holds the incoming raw data
volatile int IBI = 600;             // holds the time between beats, the Inter-Beat Interval
volatile boolean Pulse = false;     // true when pulse wave is high, false when it's low
volatile boolean QS = false;        // becomes true when Arduino finds a beat.


void setup(){
  pinMode(blinkPin,OUTPUT);         // pin that will blink to your heartbeat!
  pinMode(fadePin,OUTPUT);          // pin that will fade to your heartbeat!
  Serial.begin(9600);             // we agree to talk fast!
  interruptSetup();                 // sets up to read Pulse Sensor signal every 2mS
   // UN-COMMENT THE NEXT LINE IF YOU ARE POWERING The Pulse Sensor AT LOW VOLTAGE,
   // AND APPLY THAT VOLTAGE TO THE A-REF PIN
   //analogReference(EXTERNAL);
}


void loop(){

  if (QS == true){                       // Quantified Self flag is true when arduino finds a heartbeat
       // fadeRate = 255;                 // Set 'fadeRate' Variable to 255 to fade LED with pulse
        //Serial.println(BPM);   // send heart rate with a 'B' prefix
        QS = false;                      // reset the Quantified Self flag for next time
  }
  if((millis() - prevTime) > timeInterval){
    Serial.print(BPM);
    //Serial.print("T"); Serial.print(temperature);
    //Serial.print("W"); Serial.println(warning);
    prevTime = millis();
  }


  delay(20);                             //  take a break
}
```

Interrupt Code

```
  volatile int rate[10];                    // used to hold last ten IBI values
volatile unsigned long sampleCounter = 0;          // used to determine pulse timing
volatile unsigned long lastBeatTime = 0;           // used to find the inter beat interval
volatile int P =512;                      // used to find peak in pulse wave
volatile int T = 512;                     // used to find trough in pulse wave
volatile int thresh = 512;                // used to find instant moment of heart beat
volatile int amp = 100;                   // used to hold amplitude of pulse waveform
volatile boolean firstBeat = true;        // used to seed rate array so we startup with reasonable BPM
volatile boolean secondBeat = true;       // used to seed rate array so we startup with reasonable BPM
```

```
void interruptSetup(){
  // Initializes Timer2 to throw an interrupt every 2mS.
  TCCR2A = 0x02;     // DISABLE PWM ON DIGITAL PINS 3 AND 11, AND GO INTO CTC MODE
  TCCR2B = 0x06;     // DON'T FORCE COMPARE, 256 PRESCALER
  OCR2A = 0X7C;      // SET THE TOP OF THE COUNT TO 124 FOR 500Hz SAMPLE RATE
  TIMSK2 = 0x02;     // ENABLE INTERRUPT ON MATCH BETWEEN TIMER2 AND OCR2A
  sei();             // MAKE SURE GLOBAL INTERRUPTS ARE ENABLED
}


// THIS IS THE TIMER 2 INTERRUPT SERVICE ROUTINE.
// Timer 2 makes sure that we take a reading every 2 miliseconds
ISR(TIMER2_COMPA_vect){                         // triggered when Timer2 counts to 124
    cli();                                      // disable interrupts while we do this
    Signal = analogRead(pulsePin);              // read the Pulse Sensor
    sampleCounter += 2;                         // keep track of the time in mS with this variable
    int N = sampleCounter - lastBeatTime;       // monitor the time since the last beat to avoid noise

//  find the peak and trough of the pulse wave
    if(Signal < thresh && N > (IBI/5)*3){       // avoid dichrotic noise by waiting 3/5 of last IBI
        if (Signal < T){                        // T is the trough
            T = Signal;                         // keep track of lowest point in pulse wave
         }
       }

    if(Signal > thresh && Signal > P){          // thresh condition helps avoid noise
        P = Signal;                             // P is the peak
       }                                        // keep track of highest point in pulse wave

  //  NOW IT'S TIME TO LOOK FOR THE HEART BEAT
  // signal surges up in value every time there is a pulse
if (N > 250){                                   // avoid high frequency noise
  if ( (Signal > thresh) && (Pulse == false) && (N > (IBI/5)*3) ){
    Pulse = true;                               // set the Pulse flag when we think there is a pulse
    digitalWrite(blinkPin,HIGH);                // turn on pin 13 LED
    IBI = sampleCounter - lastBeatTime;         // measure time between beats in mS
    lastBeatTime = sampleCounter;               // keep track of time for next pulse

         if(firstBeat){                         // if it's the first time we found a beat, if firstBeat == TRUE
             firstBeat = false;                 // clear firstBeat flag
             return;                            // IBI value is unreliable so discard it
            }
         if(secondBeat){                        // if this is the second beat, if secondBeat == TRUE
            secondBeat = false;                 // clear secondBeat flag
               for(int i=0; i<=9; i++){         // seed the running total to get a realisitic BPM at startup
                    rate[i] = IBI;
                    }
            }

    // keep a running total of the last 10 IBI values
    word runningTotal = 0;                      // clear the runningTotal variable

    for(int i=0; i<=8; i++){                    // shift data in the rate array
          rate[i] = rate[i+1];                  // and drop the oldest IBI value
          runningTotal += rate[i];              // add up the 9 oldest IBI values
        }
```

```
    rate[9] = IBI;                          // add the latest IBI to the rate array
    runningTotal += rate[9];                // add the latest IBI to runningTotal
    runningTotal /= 10;                     // average the last 10 IBI values
    BPM = 60000/runningTotal;               // how many beats can fit into a minute? that's BPM!
    QS = true;                              // set Quantified Self flag
    // QS FLAG IS NOT CLEARED INSIDE THIS ISR
    }
}

  if (Signal < thresh && Pulse == true){    // when the values are going down, the beat is over
      digitalWrite(blinkPin,LOW);           // turn off pin 13 LED
      Pulse = false;                        // reset the Pulse flag so we can do it again
      amp = P - T;                          // get amplitude of the pulse wave
      thresh = amp/2 + T;                   // set thresh at 50% of the amplitude
      P = thresh;                           // reset these for next time
      T = thresh;
     }

  if (N > 2500){                            // if 2.5 seconds go by without a beat
      thresh = 512;                         // set thresh default
      P = 512;                              // set P default
      T = 512;                              // set T default
      lastBeatTime = sampleCounter;         // bring the lastBeatTime up to date
      firstBeat = true;                     // set these to avoid noise
      secondBeat = true;                    // when we get the heartbeat back
     }

  sei();                                    // enable interrupts when youre done!
}// end isr
```

APPENDIX III: GPS and GSM 2 Code for Arduino U2

```
int count=0;
#include <SoftwareSerial.h>
#include <String.h>
#include <TinyGPS.h>
TinyGPS gps;
SoftwareSerial ss(2,3);
#define INDICATE 13
SoftwareSerial sim800l(2, 3); // RX, TX
char str[70];
char *test="$GPGGA";
char logitude[10];
char latitude[10];
int led=12;
int sendGPS=0; //confirmation that gps is linking with setelite variable
int sendNow=0; //gps is now stable
const int buttonPin =9;
int buttonState = 0;
int stopNow=0; //stop many messages flow
void setup()
{
 Serial.begin(9600);
ss.begin(9600);
 pinMode(buttonPin, INPUT);
 sim800l.begin(4800);
 {
  while(!Serial);
 ss.begin(9600);
 delay(100);
  // lcd.begin(16,2);
 pinMode(INDICATE, OUTPUT);

 delay(10);
  }
}
void loop()
{
 bool newData = false;
 unsigned long chars;
 unsigned short sentences, failed;

 // For one second we parse GPS data and report some key values
 for  (unsigned long start = millis(); millis() - start < 1000;)
 {
  while (ss.available())
  {
   char c = ss.read();
   // Serial.write(c); // uncomment this line if you want to see the GPS data flowing
   if (gps.encode(c)) // Did a new valid sentence come in?
     newData = true;
  }
 }

 buttonState = digitalRead(buttonPin);
 if (buttonState == 1){
  sendGPS=1;

  }
```

```
 if((sendGPS==1)&&(sendNow==1)&&(stopNow==0))
  {
     digitalWrite(INDICATE, HIGH);
   Serial.print("EMERGENCY RESPONSE TRIGERED");
   SendTextMessage();
   }
  if (sim800l.available())
  {
   Serial.write(sim800l.read());
  }
   if (newData)
  {
   float flat, flon;
   unsigned long age;
   gps.f_get_position(&flat, &flon, &age);
   Serial.print("LAT=");
   Serial.print(flat == TinyGPS::GPS_INVALID_F_ANGLE ? 0.0 : flat, 6);
   Serial.print(" LON=");
   Serial.print(flon == TinyGPS::GPS_INVALID_F_ANGLE ? 0.0 : flon, 6);
   Serial.print(" SAT=");
   Serial.print(gps.satellites() == TinyGPS::GPS_INVALID_SATELLITES ? 0 : gps.satellites());
   Serial.print(" PREC=");
   Serial.print(gps.hdop() == TinyGPS::GPS_INVALID_HDOP ? 0 : gps.hdop());
  gps.stats(&chars, &sentences, &failed);
  Serial.print(" CHARS=");
  Serial.print(chars);
  Serial.print(" SENTENCES=");
  Serial.print(sentences);
  Serial.print(" CSUM ERR=");
   sendNow=1; //this prevents no co ordinates  messages
   Serial.print("positioning working");


   count++;
   Serial.print("  ");
   Serial.println(count);
  Serial.println(failed);

//This is aimed at stoping message overflow
  if(count>120){

   stopNow=0;
   Serial.print("TIME FOR ANOTHER TEXT");
   count=0;
   }
  if (chars == 0)
   Serial.println("** No characters received from GPS: check wiring **");

}
}


void SendTextMessage()
{
  Serial.println("Sending Text...");
  sim800l.print("AT+CMGF=1\r"); // Set the shield to SMS mode
  delay(100);
  sim800l.print("AT+CMGS=\"+254720288370\"\r");
```

```
 delay(100);
 sim800l.print ("PATIENT NEEDS IMMEDIATE ATTENTION AT:");
sim800l.print("http://maps.google.com/?q=");
 {
   float flat, flon;
   unsigned long age;
 gps.f_get_position(&flat, &flon, &age);
sim800l.print(flat == TinyGPS::GPS_INVALID_F_ANGLE ? 0.0 : flat, 6);//latitude cordinates to be sent to phone
sim800l.print(latitude);
sim800l.print(",");
sim800l.print(flon == TinyGPS::GPS_INVALID_F_ANGLE ? 0.0 : flon, 6);//longitude cordinates to be sent to phone
 sim800l.print(logitude);
 Serial.print("LAT=");
   Serial.print(flat == TinyGPS::GPS_INVALID_F_ANGLE ? 0.0 : flat, 6);
   Serial.print(" LON=");
   Serial.print(flon == TinyGPS::GPS_INVALID_F_ANGLE ? 0.0 : flon, 6);
 sim800l.print("\r"); //the content of the message
 delay(100);
 sim800l.print((char)26);//the ASCII code of the ctrl+z is 26 (required according to the datasheet)
 delay(100);
 sim800l.println();
 stopNow=1;
 Serial.print("Text Sent.");
  delay(100);

}
}
```

APPENDIX IV: LM35 Features

The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level;

- Calibrated Directly in degree Celsius
- Low Impedance Output, 0.1 W for 1 mA Load
- Linear + 10 mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at +25°C)
- Rated for Full −55°C to +150°C range
- Suitable for Remote Applications
- Low Cost Due to Wafer-Level Trimming
- Operates from 4 to 30 V
- Less than 60-µA Current Drain
- Low Self-Heating, 0.08°C in Still Air

APPENDIX IV: Photos of The Arduino Based Remote Health Monitoring System for Patients.