Smart MIoT based Cardiac Healthcare Monitoring System for Ubiquitous Healthcare Service

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THESIS ACCEPTANCE CERTIFICATE

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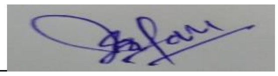
Signature: ______________  _____

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Dedication

My Life...Mr. Sajjad Hussain, Ms. Farzana Sajjad,

Mr. Malik Liaqat Ali (Late)

Beloved...Usama Sajjad, Shehzeena Rubab

Certificate of Originality

I hereby declare that this submission titled "Smart MIoT based Cardiac Healthcare Monitoring System for Ubiquitous Healthcare Service" is my own work. To the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any degree or diploma at NUST SEECS or at any other educational institute, except where due acknowledgement has been made in the thesis. Any contribution made to the research by others, with whom I have worked at NUST SEECS or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except for the assistance from others in the project's design and conception or in style, presentation and linguistics, which has been acknowledged. I also verified the originality of contents through plagiarism software.

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Sanam Nayab

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List of Abbreviations

+IN Instrumentation Amplifier Positive Input

ADC Analog-to-Digital Converter

AI Artificial Intelligence

APIs Application Programming Interface

AREF Analog Reference

AVR Alf-Egil Bogen Vegard Wollan RISC

BP Blood Pressure

BPM Beats per Minute

CLI Command Line

CS Chip Select

CVD Cardiovascular disease

DBP Diastolic Blood Pressure

DC Direct Current

DD Doctor Device

DIS Dispersed

ECG Electrocardiogram

EEPROM Electrically Erasable Programmable Read-Only Memory

EKG Electrocardiogram

EN Enable

EP Exposed Pad

FR Fast Restore

GPIO General Purpose Input/Output

GPRS General Packet Radio Service

GPS Global Positioning System

GSM Global System for Mobile Communications

GUI Graphical User Interface

HPDRIVE High-Pass Driver Output

HPSENSE High-Pass Sense Input for Instrumentation Amplifier

HTTP Hypertext Transfer Protocol

I/O Input/Output

I2C Inter-Integrated Circuit

IAOUT Instrumentation Amplifier Output Terminal

IC's Integrated Circuits

ICU Intensive Care Unit

IDE Integrated Development Environment

-IN Instrumentation Amplifier Negative Input

INT Interrupt

iOS iPhone Operating System

IoT Internet of Things

IR Infrared Radiation

ISIS Intelligent Schematic Input System

JDK Java Development Kit

LA Left Arm

LCD Liquid Crystal Display

LED Light Emitting Diode

LOD+ Leads Off Comparator Output

mA milliampere

MFIO Multifunction I/O

MIoT Medical Internet of Things

mm millimeter

mmHg millimeters of mercury

MOSI Master Output/Slave Input

Node MCU Node Micro Controller Unit

NoSQL Not Only SQL

NPM Node Package Manager

NV Non-Volatile

OPAMP- Operational Amplifier Inverting Input

OPAMP+ Operational Amplifier Noninverting Input

P1 Patient 1

PCB Printed Circuit Boards

PPG Photoplethysmography

PWM Pulse Width Modulation

RA Right Arm

REFIN Reference Buffer Input

REFOUT Reference Buffer Output

Reset RST Pin

REST Representational State Transfer

RL Right Leg

RLD Right Leg Drive Output

RLDFB Right Leg Drive Feedback Input

ROM Read Only Memory

SBP Systolic Blood Pressure

SCL Serial Clock

SCLK Clock Line for the Clock Signal

SDA Serial Data

SDKs Software Development Kit

SDN Shutdown

SDN System Shutdown Activation

SMS Short Message Service

SNR Signal-to-Noise Ratio

SpO2 Oxygen Saturation

SW Fast Restore Switch Terminal

TCP/IP Transmission Control Protocol/Internet Protocol

TWI Two-Wire Interface

Tx/Rx Transmitted/Received

UART Universal Asynchronous Receiver and Transmitter

UI User Interface

USA United States of America

V Voltage

VCC Voltage Common Collector

VEE Voltage Applied to the Transistor Emitter Leg

VIN Input Voltage Pin

WBAN Wireless Body Area Network

WBSN Wireless Body Sensor Network

WHO World Health Organization

Wi-Fi Wireless Fidelity

WLAN Wireless LAN

WPA Wi-Fi Protected Access

XML Extensible Markup Language

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Abstract

Cardiovascular disorder is the most leading cause of mortality worldwide, including Pakistan. Most cardiac disease-related fatalities are abrupt and leave little time for medical assistance to be given. Precautions are constantly necessary to avoid such impulsive unintentional deaths. In the existing Internet of Things (IoT) domain for cardiovascular monitoring, just a few heart parameters are addressed, sensors are dispersed, and needs physical patient in hospital for healthcare monitoring purposes. Also, there is no system found in a Pakistan worked in a cardiac domain. Thus, the ubiquitous healthcare mechanism for remote and real time monitoring of basic and vital cardiac parameters is the best solution for all the health issues that cardiac patients of all ages, especially the most vulnerable segments of the ageing population, are currently facing in Pakistan. This approach intends to notably reduce unnecessary hospital visits, expensive travel expenses, and the lengthy lines that are becoming intolerably uncomfortable for cardiac patients. In addition, the continuous, nonstop monitoring of key cardiac parameters is another crucial aspect of cardiac patients. Our proposed Medical Internet of Things (MIoT) kit is specifically outfitted with all the required cardiac parameters, such as Blood Pressure (BP), Heart Rate, Oxygen Level, Temperature, and Electrocardiography (ECG). The seamless delivery of an integrated IoT solution in our country with the least amount of sensor dispersion is one of the major key aspects of this arrangement. The system also consists of cloud application for continuous and remote patient monitoring and alert mechanism to enable prompt intervention by trained medical staff who will act correctly and at the appropriate moment to keep the frequency of critical events to a minimal. Our proposed methodology has undergone testing in a real medical setting. The testing of our system involves a total of 8 subjects. Both objective and subjective testing are used to evaluate our system after it has been put into place. The testing and comparison results have demonstrated that the proposed integrated kit values are significantly closer to the device utilized at the doctor's end than the dispersed kit results.

CHAPTER 1

Introduction

This chapter introduces every aspect of our research idea, including background, motivation, and research gap identification. It also describes the research objectives and the study's novelty and contributions.

1.1 Background

Cardiovascular Diseases (CVDs) and its potential consequences are among the leading causes of mortality worldwide [1]. In addition, estimates show that by 2030, this number will have risen to 23.6 million [2]. It is also termed a cardiovascular ailment, a group of abnormal symptoms that occur when the brain and heart do not receive enough oxygen and nutrients because of blockages in the body's major blood arteries [3]. Common cardiovascular illnesses include myocardial infarction (heart attack), stroke, and heart failure due to inadequate blood flow to the heart [4]. All these factors are notorious for the high rates of death, illness, and disability and the young adults have emerged as the primary victims in recent years [5]. This is probably because lifestyle factors, including being overweight, eating poorly, not obtaining sufficient sleep, and having high blood pressure or diabetes, are significant contributors to the development of cardiovascular disease. Timely treatments, such as improved medication administration and healthcare delivery, are crucial in averting most fatalities caused by cardiovascular disease [6].

Cardiovascular healthcare monitoring systems which based on the Medical Internet of Things (MIoT) may monitor, analyze, and regulate the patient's physical symptoms such as their body temperature, Blood Pressure (BP), Oxygen Saturation (SpO2), heart rate, Electrocardiogram (ECG) [7]. Implementing the Internet of Things (IoT) - based cardiac healthcare monitoring system can enhance widespread healthcare for cardiovascular ailments and illnesses. Healthcare has been one of the fastest growing IoT areas in recent years. If we are serious about improving cardiovascular health, we must move away from passive healthcare and toward omnipresent healthcare. Long wait times, expensive therapy, and frequent journeys to see specialists in another city are among the challenges faced by heart patients who are in life-threatening situations and need to be treated immediately. Things have gotten considerably worse because of a shortage of medical services in rural areas.

Many electrical gadgets worldwide are connected to the internet and receive and send data utilizing state-of-the-art network routing algorithms and software networks as part of the IoT. The IoT will bring everything together in the future [8]. The IoT technology facilitates and monitors critical human processes regardless of where they are or what they are doing. The IoT is a strategy that works by distributing the benefits of the internet to many people with minimal effort and at a low cost.

MIoT is a network of smart health devices and sensors connected to the cloud that facilitates the monitoring of patient health states and the tracking of medical staff. MIoT refers to an increasing number of IoT applications in the healthcare business, also known as healthcare IoT. Sensors and applications for remote healthcare monitoring, telemedicine consultation, and delivery are just a few examples of the enormous range of IoT devices and applications that may be generated in this way. Advanced diagnostics, robotic surgery, and much more are all possible thanks to the IoT in the medical field. Due to advances in telemedicine and other related technologies, MIoT is becoming increasingly relevant as health and healthcare become more widely disseminated. There are new prospects for improving patient care and managing the inherent complexity of the healthcare sector through enhanced automation, safety, and other technology improvements provided by medical IoT.

An IoT-based cardiac healthcare monitoring system includes various IoT sensors and technologies that need to be connected to the patient's body to receive sensory data and send data to the cloud for further monitoring, processing, and decision-making that is beneficial for saving the patient's life before any tragedy occurs. Many IoT systems for cardiac patient monitoring are based on analog, digital, and wearable sensors/devices. A wide range of ready-made and wearable watches are available for fitness trackers and health monitoring purposes. Various intelligent and wearable technologies are available for cardiac patients to track multiple aspects of their cardiac wellness. Various sensors, including heart rate/pulse sensors, temperature sensors, BP sensors, blood oxygen sensors, and ECG sensors, are used to the interface in an IoT environment to obtain sensory parametric values from the patient body, transmit data via specific communication technologies to the cloud, apply machine learning practices on the learned parametric values, and generate alert messages. Here are the basic and vital parameters mentioned for cardiovascular patients:

Heart Rate:

Heart monitoring plays a critical role in diagnosing, identifying, and categorizing patient cardiac problems. Identifying a patient's high or low heart rate can lead to various cardiac diseases and problems. IoT was always there to help monitor the patient's heart rate utilizing analog or digital sensors and gadgets. The heartbeat sensor can measure a patient’s heart rate in Beats per Minute (BPM). Human BPM ranges between 60 to 90. The BPM is divided into two categories: low (less than 60) and high (more than 90) [9].

Temperature:

The creation of a cardiac healthcare monitoring system relies heavily on the measurement of body temperature. The body's temperature may be measured using a variety of analog and digital temperature sensors. Celsius and Fahrenheit are two different units of measurement for temperature. The body's normal temperature is 97 degrees Fahrenheit (36.1 degrees Celsius) to 99 Fahrenheit (37.2 degrees Celsius) [10]. A high temperature or fever is when your body temperature is 100 degrees Fahrenheit (38 degrees Celsius) or higher.

Blood Pressure (BP):

Cardiovascular abnormalities can be detected and diagnosed by monitoring a person's BP. Various sensors and technologies can be used to measure a person's BP. The BP sensors or devices provide systolic and diastolic range data that a physician should evaluate. Low BP is also known as "hypotension," and the normal range is less than 120/80 millimeters of mercury (mmHg). The 90/60 mmHg range is considered hypotensive. Hypertension is the medical term for blood pressure that exceeds 140/90 millimeters of mercury [11].

Oxygen Saturation:

Several IoT-based blood oxygen sensory devices, such as pulse oximetry sensors, can be used to monitor a patient's SpO2 combined with their heart rate to acquire blood oxygen levels. There are also ready-made wearable gadgets on the market that can help patients reach a high blood oxygen saturation level. The proportion of oxygen in the blood is measured. Blood oxygen saturation ranges from 90 to 100. A normal oxygen level is usually 95 or higher [12].

ECG Unit:

The electrical impulses produced by the heart are recorded on paper or digitally as an ECG. Another name for it is an Electrocardiogram (EKG). Heart rate, heart rhythm, and other details about the heart's health are all determined using the ECG. Heart arrhythmias, heart attacks, pacemaker functionality, and heart failure can all be identified with ECG.

ECGs may be examined by looking at waveform elements (PQRST) [13] in figure 1. These waveform elements represent electrical activity in the heart. The P wave is the first rising wave on the ECG trace. That means the atrium is contracting. The Q wave, a modest downward deflection, is followed by R, a bigger upward deflection, a peak, and a downward S wave. This QRS complex shows contraction and depolarization of the ventricles. The T wave, which often has a smaller upward waveform and represents ventricular re-polarization, comes last.

Finding out if your high blood pressure has harmed your heart or blood vessels with an ECG might be helpful. As a result, an ECG may be requested when you are initially diagnosed with high blood pressure.

The following are some things an ECG reading can identify:

- Cholesterol blocks the blood vessels that supply your heart.
- Previous heart attack
- An enlarged heart on one side
- Unusual heartbeats

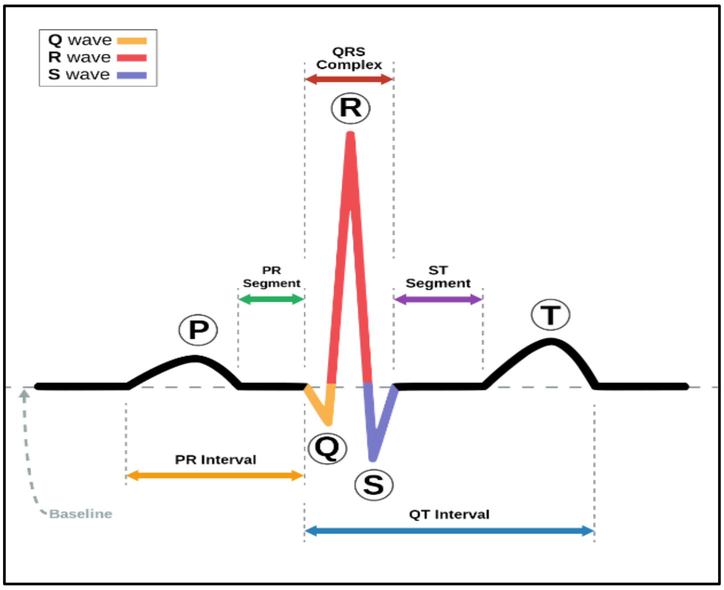

Figure 1: ECG Waveform [14].

1.2 Motivation

We have noticed by analyzing the facts that cardiovascular disease is the leading cause of death in the world. According to World Health Organization (WHO) report of 2021, 17.9 million people died each year from CVDs, an estimated 32% of all deaths worldwide [15]. Arrhythmia is the most common cause of cardiac arrest and irregular heartbeat rhythms [16]. Premature heartbeat, tachycardia, and bradycardia are all limited subsets of this condition, each with its distinct causes. According to the most recent data from the WHO, Arrhythmia is the leading cause of mortality in at least 15% of cases. Cardiovascular disorders are to blame for almost 80% of all unexpected deaths [17] as shown in figure 2. A stroke can be caused by a condition known as atrial fibrillation. Ventricular Tachycardia, on the other hand, is primarily responsible for the cessation of normal cardiac function and the ensuing abrupt death, whereas blood vessel congestion is responsible for cardiac arrest. According to the aging population of Pakistan, as of 2019, 15 million people are over aged 60, which is 7% of the total population. The older population is expected to double to 12% in 2050 with 40 million people over 60 [18]. The traditional cardiac healthcare system [19] [20] [21] has been criticized for several inherent faults, including insufficient parameters, sensor dispersion, lengthy waiting times, especially for old patients, high costs, extensive distances to go to medical facilities, especially for old age people, and their frequent visits to physicians. The IoT is widely regarded as the best possible answer to the problem of monitoring patients cost-effectively around the clock.

We need to go from a passive to a ubiquitous state to strengthen our ability to combat various heart disorders and provide ease to old, aged people. The system's critical need is a concurrent patient health examining system for cardiac patients. Non-invasive sensors [22] and frequent monitoring of critically vital cardiac parameters have become more crucial in recent years for the system's proper function. First and foremost, 24/7 monitoring is the goal of the continual cardiac healthcare monitoring system. However, the lack of infrastructure and resource constraints in world nations like Pakistan are the main obstacles to implementing such a system. Body temperature, BP, SpO2, heart rate, are the basic and ECG is the vital physical symptoms that may be monitored and controlled by MIoT-based cardiovascular healthcare monitoring systems. Current research [23] [24] [25] has been found towards the creation of a MIoT-based cardiovascular healthcare monitoring system. The following are the shortcomings in the current studies [26] [27]:

- Lack of an IoT-based cardiac healthcare monitoring system that addresses all the basic and vital cardiac parameters.
- No integrated solution addresses all the cardiac parameters.
- Absence of the system having remote and real-time monitoring of old patients at home with a notification alert to the family member if patient conditions become abnormal.
- There is an absence of IoT-based cardiac solution in Pakistan.

Figure 2: WHO Statistics- Proposed System Motivation.

1.3 Problem Statement

The cardiovascular healthcare monitoring systems, which only address a single or few heart parameters having dispersed sensors, do not provide a comprehensive and integrated solution for cardiac patients. The complete IoT-based cardiac healthcare monitoring system consists of basic and vital healthcare parameters such as the patient's heart rate, BP, temperature, SpO2, and ECG [7]. But much of the recent work has been done for the cardiac system, which only addresses limited parameters using dispersed sensors [28] [29]. Pakistan is considered one of the fast-growing and developing countries. But there is complete negligence found in the literature [30] for the implementation of MIoT-based cardiac solutions for cardiac patients. Further, by doing the literature analysis of almost 42 studies from 2016 to 2021, we came to know the following problems which need to be solved:

- First, there is an absence of a MIoT-based cardiac healthcare monitoring system that must address all the basic and vital parameters of the cardiac patient.
- Secondly, the existing systems are being developed using locally dispersed sensors. So, there is a lack of an integrated MIoT-based cardiac healthcare system.
- Thirdly, the previous studies were limited to remote and real-time patient monitoring and

generating notification alerts if cardiac patient conditions became severe. So, there is an absence of a ubiquitous system that can monitor old patients' health conditions at home by continuous monitoring with an additional feature of generating an alarm if the patient's condition is found abnormal.

- Fourthly, there is a lack of a cloud-based integrated solution for cardiac patients in Pakistan.

1.4 Research Objectives

A few key objectives of the study under discussion are:

- To propose an IoT-based cardiac healthcare monitoring system consisting of an integrated solution kit.
- To develop an integrated solution for cardiac patients that must address all the basic and vital parameters of heart patients.
- To propose an integrated cloud based IoT solution for cardiac patients for continuous and remote patient monitoring with an additional notification feature if the patient's condition is detected as abnormal.
- To develop an integrated remote solution for cardiac patients in our Country, which was not done before.

1.5 Novelty and Contribution

The following are some significant contributions of the performed study:

- It implements an integrated solution for cardiac patients.
- It provides a complete solution addressing all cardiac patients' basic and vital cardiac parameters.
- It also implements a ubiquitous healthcare system consisting of an additional notification or emergency alert feature.
- It delivers a cloud based MIoT cardiac system with integrated sensors, which has never been implemented in Pakistan.

1.6 Thesis Organization

The organization of the presented dissertation is as follows:

- "Literature Review" provides a comprehensive summary of research conducted from 2016 to 2021.
- "Implementation" presents the details of the implemented system along with the working of that proposed system.
- "Testing and Results" presents the testing of the proposed system and results obtained from the proposed system.
- In the end, "Conclusion and Future Work" wraps up the presented work by discussing its summary, shortcomings and suggesting possibilities for further investigation.

CHAPTER 2

Literature Review

This chapter explains the previous studies for the MIoT-based cardiac healthcare monitoring system and its findings. From 2016 through 2021, the most significant reflections and earlier projects in cardiology have been covered. Two main categories are used to organize literature. The first category pertains to those scholarly investigations using dispersed sensors addressing the specific number of cardiac parameters in cardiac healthcare systems. The second is based on earlier studies that used integrated sensors addressing a particular number of cardiac parameters to construct cardiac systems. Afterward, we provided a critical analysis based on the literature review findings. The detail of the literature we have covered are given below:

2.1 IoT-Based Dispersed Cardiac Systems

The research authors presented 2016 an IoT-based system for tracking and monitoring patients' health in real time. Global Positioning System (GPS)/Global System for Mobile Communications (GSM)/General Packet Radio Service (GPRS), and a web-based application are all components of the system [23]. IoT dispersed sensors like the MCP9700 cardiac pulse, and temperature sensor is employed to collect patient sensory data. The Arduino microcontroller is used to apply thresholds, and the GPS module is used to track the device's location. Doctors or worried family members of the patient are alerted through Short Message Service (SMS) when a patient's health metrics fall below a pre-determined threshold level. An email can also be delivered as a report on a patient's email and a warning regarding the patient's health. Patients' medical records are evaluated by a doctor and a nurse using a web program.

An application's web-based, flexible architecture has been built with Representational State Transfer (REST) and Application Programming Interface (APIs). ECG aberrant and ordinary representations were created using simulation tools in the proposed system.

The research publication in 2017 presented a heart disease monitoring system based on ubiquitous IoT technology as a remedy for heart patients [24]. When a patient's condition deviates from the criteria set by the proposed systems, a trigger is created at the doctor's desk and sent to the system for review. The suggested system specifies four different ways to communicate. Sensory data can be transmitted to a distant center and made available to doctors in real-time via a first kind of data transmission known as "real-time data transmission." In the second mode, data is sent at a predetermined interval, which medical professionals dictate. If a patient's condition isn't normal, the triggers are created in a third mode established by comparing threshold values set by doctors. A fourth communication route is used to send monitored data to a server that is remotely accessible if the patient expresses concern about it. Sensors that can detect oxygen levels and pulse sensors were also used in the prototype.

Using an IoT kit for cardiac patients with an effective alarm system was the subject of this research in 2017 [31]. The dispersed sensors KY-039 heart sensor and 18DS20 temperature sensor are used in an IoT kit designed for cardiac patients. Sensory data from the patient's body is transferred to a microcontroller platform and shown on Liquid Crystal Display (LCD) screen. The Wireless Fidelity (Wi-Fi) module ESP8266 communicates sensory data to the internet/cloud. GSM and phone calls or text messages are used to send alerts to the affected person’s phone number and notify his/her family and friends.

Wireless Body Sensor Network (WBSN) presented in this system has been used to monitor cardiac patients' health utilizing a three-tiered design in 2018 [32]. Data from associated sensors (Heart Sensor, SpO2 MAX30100 and Temperature Sensor) are collected from the patient's body using an Arduino Nano board in Tier 1. Wi-Fi ESP8266 module and Hypertext Transfer Protocol (HTTP) protocol communicates sensory data to the server in Tier 2. Sensory data is also stored, displayed, and processed on Tier 2. The alerts system in tier 3 is used to notify the doctor when something goes wrong. The Thing Speak IoT application uses the data delivered to distant site servers. An alert is provided to emergency personnel through text messages on their smartphones in the event of an emergency. Login credentials allow medical professionals such as doctors and nurses to access patient data. This system is also capable of plotting a sampled ECG. The Fitbit gadget is used to compare data from heart tests. The plan was able to reach a 95% accuracy rate.

Heart rate sensors were used in developing an IoT kit to detect heat strokes in 2019 [33]. Input data for the system comes from the patient's body through a dispersed heart rate sensor and a temperature sensor (18DS20). When a patient places their finger on a heartbeat sensor, Light Emitting Diode (LED) is utilized to detect the patient's heartbeat. The Arduino software's source code is executed and matches the defined thresholds. LCD screen displays these two parameters' values. The alert system sent warning SMS messages to the patient's phone or the phone of a worried family when two of the patient's criteria matched. An attack is suspected when the patient's heart rate exceeds a certain threshold.

Using a machine learning method, this study in 2019 [30] proposes creating a wearable IoT solution for cardiac patients that can assess their heart rate and temperature directly from their bodies. To communicate with a mobile phone, Bluetooth is used to transport data from a pulse sensor and temperature sensor to an Arduino UNO. To design a well-organized Printed Circuit Board (PCB) solution for an IoT kit, the wearable device's hardware requirements increased from Arduino UNO to Arduino mini, but the sensors stayed the same. The sensors and other components are arranged on a PCB board to provide a wearable solution for cardiac patients. Mobile application data may also be used to keep track of a patient's condition and send an emergency alert. 4 Subjects performed various activities, such as sitting and walking, while ECG waves were analyzed on MATLAB to see how their hearts acted. A decision tree technique is developed for identifying aberrant ECG signals after noise reduction, and the Fourier transform is performed on ECG signals. A warning message will be sent to the user if the situation is abnormal. Additionally, ten publicly accessible datasets of ECG from cardiac patients were utilized to test the proposed technique.

Sensory modules were used in this study in 2020 to create a detection system for heart attacks. To construct an IoT kit, dispersed sensors like temperature and BP sensors are employed [34]. The system's primary goal is to make remote patient health monitoring accessible via a web application while offering a comfortable and accurate method. The design included sensors to obtain a few heart rate readings. The patient's heartbeat is measured using a pulse sensor. It can send sensor data from a mobile device over Bluetooth to a web application. The patient's medical history and current state are stored in a web application. Some of the patient's required coordinates (longitude, latitude, speed, and time) were captured and communicated using Google's GPS module. When a patient's condition veers off course, alarms and notifications are issued to the individuals who need to know.

The proposed solution in 2020 [27] includes a health monitoring dispersed IoT kit explicitly designed for the elderly. The suggested IoT kit includes ECG module AD8232, LM35 series temperature sensor, MPX10 series pressure sensor, and pulse sensor. Patients' bodies provide the input for a real-time health monitoring kit, which measures ECG signals, temperature, blood pressure, and oxygen levels. To transport data wirelessly from the patient's body to Arduino and finally to the Raspberry pie module. Information is transmitted to a doctor via the internet or a mobile app so that they can monitor it and act as necessary. The doctor's application and laptop show the patient's current health status in real-time. Low-cost and effective health care services, especially for the elderly, would be provided by this suggested module.

Automation is essential in today's environment. When it comes to medicine, it can have an impact. It lessens the burden on humans while increasing human well-being. Automated processes are more precise than manual ones. The patient health monitoring system is one of the computerized systems that measure numerous health-related indicators of the patient. IoT platforms are helping the medical industry thrive. Quickly obtaining information about the patient is facilitated by this method. Temperature, pressure, heart rate, glucose level, and oxygen level are some of the most important physical characteristics to be monitored. The LM35 sensor to monitor the temperature in the research 2021 [35]. A pressure sensor employed (digital sphygmomanometer) to keep tabs on pressure. A heartbeat sensor is used to monitor the rate of heartbeats (LM358 operational amplifier). The oxygen content of hemoglobin may be measured with pulse oximeters. A glucometer is a device that measures glucose in the blood. Node-MCU serves as the microcontroller in this design. They may use this Wi-Fi module to upload data from sensors to the cloud and Google sheets. A doctor's email or text message will be sent to the patient's relative and doctor if there is any disagreement in the measured value.

In the section above, we have presented a literature review based on the cardiac systems developed in the past few years using dispersed sensors. Those studies were found to address the limited number of cardiac parameters. The following section presents research based on integrated sensors in a cardiac healthcare domain.

2.2 IoT-Based Integrated Cardiac Systems

A wearable band and a mobile phone app were the foundation of this IoT kit for cardiac patients, presented in this research in 2016 [36]. Due to this technology, an ambulance or mobile user is alerted to a patient's serious state in a timely manner. The device uses a wearing band to monitor the patient's heart rate and blood pressure. The patient wears a wristwatch-like wearable band that monitors the patient's heart rate, pulse rate, and blood pressure. Sensational data is transmitted to a mobile device through Bluetooth or Wireless LAN (WLAN) once the patient's body provides input values. Android phones are required to run the mobile app. SMS or phone call is sent to the patient's emergency service or concerned person based on the values obtained from the patient's body, analyzed with the help of big data analytics techniques, and the pulse sensor additionally acquires technologies for the data set.

The ultimate goal of this work [32] is to design and implement a health monitoring system for cardiac patients, utilizing the MAX30100 integrated sensor to track key body characteristics, notably those linked to heart issues, such as oxygen level and heart rate. Using a Wireless Body Area Network (WBAN) with a three-tiered architecture and a wide range of sensors, we have developed a prototype for automated health monitoring in cardiac Intensive Care Unit (ICU) patients. Data from sensors are gathered in tier I by an Arduino Nano board using an ATmega328P microcontroller and then sent to a server in tier II through Wi-Fi wireless connection using an ESP8266. Tier III uses the already-present internet to transmit information to distant servers for processing by the Thing Speak IoT software.

This research [37] aims to create an IoT system for forecasting individual cardiac arrests distinct from existing eHealth based IoT solutions due to the inherent integration of its sensing and communication components. They performed a series of tests to evaluate and distinguish between normal and abnormal heart rate patterns using the embedded sensors' output as part of the integrated process. Sensors are incorporated within the smartphone, which the subject carries in their pocket or hands. While the individual goes about daily activities, the inbuilt ECG and temperature sensors record vital signs. The smartphone will evaluate the data to determine if the user's state is normal or abnormal after receiving it through a low-power Bluetooth connection channel. The Android platform does a quantitative study of the user's heart rate, allowing the user to observe real-time graphs of the user's ECG signal and body temperature.

It is an effective alternative to center-based cardiac rehabilitation at points in the recovery and preventive phase. Most telerehabilitation technologies now use count steps to measure activity. Cyclists, on the other hand, are under-appreciated in this environment. Cycling is a popular pastime for many individuals and is an integral aspect of rehabilitation programs at rehabilitation centers. The research [38] designed 2018, a smartphone app to help cardiac patients exercise safely and happily on picturesque routes or routes in their neighborhood using GPS-guided navigation. They conducted a four-week field trial in which we tested the mobile application with 14 cardiac patients to see how well it worked. In this study, cardiac patients enjoy riding with an application, are more likely to go on longer bike rides, and can meet cardiac patients required weekly physical activity level.

2.3 Critical Analysis

The above section presents the major studies from 2016 to 2021 working on implementing a cardiac healthcare monitoring system using dispersed or integrated sensors. Table 1 shows a detailed overview of 42 studies in the research gap identification by literature analysis. Our literature analysis was based on categorizing dispersed, or integrated sensor kit proposed in a specific country and the number of cardiac parameters addressed in an existing system. Table 1 below mentioned the total number and list of cardiac parameters addressed in the past studies, along with the type of kit or sensors used to implement the cardiac healthcare monitoring system in the respective country. As mentioned in the detailed overview of the literature cited in table 1 below, most of the studies used dispersed sensors for the implementation of the cardiac system. Few studies have an un-doubly used integrated kit, about they did not address all the essential and vital parameters of the cardiac patient. The studies [36] [38] used an integrated kit. Still, they addressed only two cardiac parameters (BP, Heart Rate) (SpO2, Heart rate) of the cardiac patient, which is not enough for the complete integrated solution of the cardiac system. Similarly, the research study [37] used a self-made integrated kit but addressed only three cardiac parameters (ECG, BP, SpO2) of the patient body. Continuous monitoring and managing the essential and vital parameters of the cardiovascular healthcare monitoring system is a mandatory factor for saving the patient's life. Any parameter missed in the system can compromise the patient’s life. Only a single literature study [27] was found to address all the basic and vital cardiac parameters (BP, Heart Rate, SpO2, Temperature, ECG) of the patient body but using the dispersed sensors. So, by doing the deep analysis and observation of at least 42 studies, we came to know that no research has been done in a MIoT cardiac domain that consists of an integrated kit solution based upon addressing all the essential parameters of the patient body. There is no study found for managing all the necessary and vital parameters in an integrated solution with ubiquitous access. In previous literature among the 42 studies, India has worked on 24 studies, the United States of America (USA) in 4 studies, Iran in 3 studies, China in 2 studies, Taiwan in 2 studies, United Arab Emirates (UAE) in 1 study, Greece in 1 study, Romania in 1 study, Australia in 1 study, the Netherlands in 1 study, Malaysia in 1 research and Bangladesh in 1 study. Pakistan did not find in previous literature to work and contribute to the MIoT based cardiac healthcare solution with cloud service. Hence, there is still a need to implement MIoT-based cardiac healthcare integrated solution with ubiquitous access in Pakistan. The study under consideration is conducted with the same goal: to fill this research gap and gain insights of outcomes.

Year	**No. of Cardiac Parameters Addressed**	**List of Cardiac Parameters Addressed**	**Type of Kit**	**Country**
2016 [23]	2	Temperature, Pulse Rate	Dispersed	UAE
2016 [36]	2	Heart Rate, BP	Integrated Wrist Band	India
2016 [28]	1	Pulse Rate	Dispersed	India
2016 [30]	1	ECG	Dispersed	Greece
2017 [24]	4	ECG, BP, Pulse Rate, SpO2	Dispersed	China
2017 [39]	1	Pulse Rate	Dispersed	India
2017 [31]	2	Pulse Rate, Temperature	Dispersed	India
2017 [40]	2	BP, Pulse Rate	Dispersed	India
2017 [25]	4	ECG, BP, Temperature, Heart Rate	Dispersed	India
2017 [41]	1	ECG	Dispersed	USA
2018 [32]	2	SpO2, Heart Rate	Integrated	India
2018 [42]	1	Pulse Sensor	Dispersed	India
2018 [43]	1	Pulse Sensor	Dispersed	India
2018 [44]	2	ECG, Pulse Rate	Dispersed	India
2018 [45]	3	ECG, Pulse Rate, SpO2	Dispersed	India
2018 [46]	3	Temperature, BP, Heart Rate	Dispersed	India
2018 [37]	3	ECG, BP, SpO2	Integrated	USA
2019 [33]	2	Temperature, Heart Rate	Dispersed	India
2019 [30]	3	ECG, Temperature, Pulse Rate	Dispersed	USA
2019 [47]	2	Temperature, Heart Rate	Dispersed	India
2019 [48]	1	ECG	Dispersed	India
2019 [49]	2	ECG, Pulse Rate	Dispersed	USA

2019 [38]	2	BP, Heart Rate	Integrated	India
2019 [26]	3	ECG, BP, Heart Rate	Dispersed	Bangladesh
2019 [50]	1	ECG	Dispersed	India
2019 [51]	1	ECG	Dispersed	Taiwan
2020 [52]	1	ECG	Dispersed	India
2020 [34]	3	Temperature, BP, Heart Rate	Dispersed	India
2020 [53]	1	Heart Rate	Dispersed	India
2020 [27]	5	ECG, Temperature, BP, Pulse Rate, SpO2	Dispersed	India
2020 [54]	1	ECG	Dispersed	India
2020 [55]	2	ECG, Heart Rate	Dispersed	Malaysia
2020 [56]	2	ECG, Temperature	Dispersed	Romania
2020 [57]	1	ECG	Dispersed	Australia
2020 [19]	1	ECG	Dispersed	Netherlands
2020 [20]	2	ECG, Heart Rate	Dispersed	Iran
2021 [9]	2	BP, Heart Rate	Dispersed	Iran
2021 [21]	1	ECG	Dispersed	India
2021 [58]	1	ECG	Dispersed	Taiwan
2021 [59]	1	ECG	Dispersed	China
2021 [60]	3	ECG, Pulse rate, SpO2	Dispersed	Iran
2021 [61]	1	ECG	Dispersed	India

Table 1: An overview of the research studies covered in the Literature Review.

CHAPTER 3

Implementation

In this chapter, we have discussed the implementation of our proposed system. In the first section, we mentioned the integrated kit development for cardiac healthcare monitoring system which consists of the overall working of the proposed integrated kit solution, its hardware components and software aspects. In the next section, we have also covered the dispersed kit development along with its working and components in detail.

3.1 Integrated Kit for Cardiac System

For the implementation of our proposed integrated solution and to compare it with the existing dispersed sensors, two types of kits were designed: integrated and dispersed. The dispersed kit comprises sensors placed at various locations on the patient's body, resulting in sensor dispersion. The integrated kit combines multiple sensors into a single integrated sensor, which is expected to provide a more accurate and efficient monitoring system.

Our proposed integrated system for cardiac healthcare monitoring system consists of an Integrated sensor (MAX32664), ECG AD8232 sensor**,** and DS18B20 sensor connected to the patient body. Our integrated kit's MAX32664 sensor is essential for simultaneously collecting the 3 parametric data (heart rate, oxygen saturation and BP). The MAX32664 sensor was exported from the Bangalore (India) to propose an integrated solution at our country. The MAX32664 is an integrated sensor that combines multiple sensors into one compact and efficient package. It is designed to provide accurate and reliable monitoring of various physiological parameters such as heart rate, oxygen, and blood pressure. The integration of multiple sensors into a single package result in a more streamlined and efficient monitoring system, which is particularly beneficial for wearable devices and remote monitoring applications. The MAX32664 is also designed to consume minimal power, making it ideal for battery-powered devices. Overall, the MAX32664 is a high-performance integrated sensor that offers significant advantages over traditional dispersed sensor systems. In our integrated system solution, the other 2 parametric values (temperature and ECG) must be obtained from the DS18B20 and ECG AD8232. The ECG AD8232 sensor and DS18B20 are also used in our proposed integrated solution for cardiac monitoring purposes. ECG AD8232 sensor used to measure the electrical activity of the patient heart and produce a signal that can be processed and analyzed to provide information about the heart's condition and function. DS18B20 is a digital temperature sensor that can be used for body temperature monitoring.

In our proposed integrated solution, the Integrated sensor (MAX32664), ECG AD8232 sensor, and DS18B20 sensor need to be attached to the patient body. The ECG AD8232 sensor and DS18B20 sensor are connected to the same Node MCU, while the MAX32664D is connected to the other Node MCU. The collected data from both nodes is transmitted via Wi-Fi to the IoT firebase cloud, which allows the patient's healthcare data to be viewed by both the user and the doctor. This integrated kit enables doctors or family members to monitor a patient's health condition through a mobile application, which can be installed on any side. The mobile application also has a feature that sends a notification alert if the patient's condition is abnormal. Furthermore, the firebase cloud saves the patient's healthcare data and transmits it to the mobile application for further Artificial Intelligence (AI) processing. The detail working of our integrated kit is as follows:

1. Firstly, MAX32664D [62] used as an integrated senor that is a variant of the MAX32664 sensor-hub family that enables users to capture raw data and calculate systolic and diastolic BP, SpO2**,** and heart rate data through finger contact. The part is preprogrammed with the firmware, drivers, and algorithms required to interface with the MAX30101 sensor device through an I2C port. The I2C slave interface is also used for establishing communication with a host microcontroller. MAX32664D can measure the SpO2, pulse rate and blood pressure using some principles. In health sensing designs, the MAX32664D is typically connected to a host microcontroller through the I2C bus. The reset and the start-up in Application or Bootloader mode are controlled by two General Purpose Input/Output (GPIO) pins (RSTN and Multifunction Input/Output-MFIO). To trigger a host interrupt for an I2C connection, an MFIO pin is activated in Application mode. The MAX32664D is connected to the MAX30101 optical sensor utilizing a second I2C bus. The algorithm does not use accelerometer information. Architecture diagram of MAX32664D is shown in the figure 3 below:

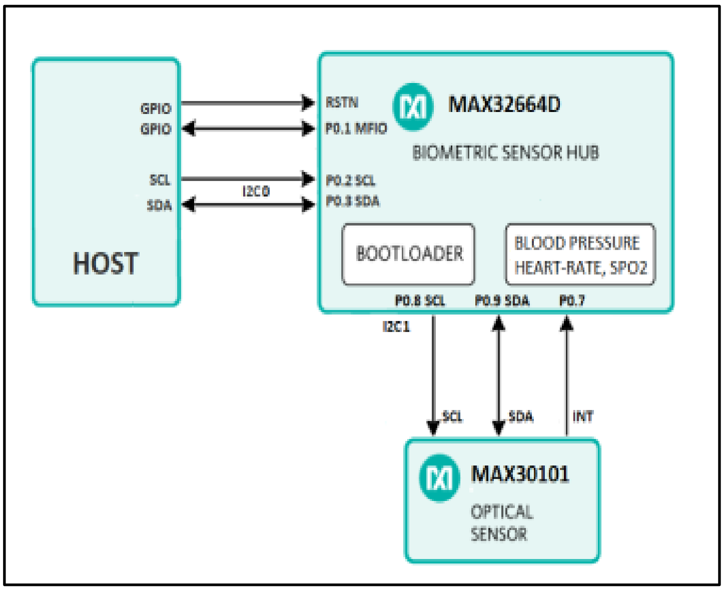

Figure 3: Architecture Diagram of MAX32664D [62].

Calibration of SpO2 and Blood Pressure Trending (BPT) Algorithm: Calibration of SpO2 Coefficients for Final Product is described below:

Calibration must be done once in a controlled setting due to variations in the final product's physical construction and optical shield. To guarantee accurate SpO2 readings, this process is crucial. This is done in a normal laboratory setting using a reference SpO2 device to calculate the A, B, and C calibration coefficients. Once the three calibration factors have been determined, they must be programmed into the MAX32664D before the algorithm can begin.

However, they must first be changed to 32-bit integer notation by means of the following:

Aint32 = round (105 x a)

Bint32 = round (105 x b)

Cint32 = round (105 x c)

For example, the default measured calibration coefficients are:

a = 1.5958422

b = -34.659664

c = 112.68987

They are sent to the MAX32664D in integer format after conversion:

Aint32 = round (105 x a) = 0x00026F60

Bint32 = round (105 x b) = 0xFFCB1D12

Cint32 = round (105 x c) = 0x00ABF37B

Every time you reboot your MAX32664D, you can reload the calibration coefficients from the host flash. The BPT method is activated in Estimation mode to carry out the SpO2 calibration procedure. The calibration procedure typically requires R values. It's important to remember that the program will keep updating R values even after completion.

Calibration of BPT Algorithm for a User is described below:

To fine-tune the estimation algorithm, everyone must go through a testing procedure. To begin, a medically authorized device is usually used to measure the subject's systolic and diastolic blood pressure three times. The MAX32664D is then given these three numbers as standards, and a calibration measurement is carried out. It takes about a minute to complete this. once the testing is finished. An internal calibration vector is created and saved in Memory. If the MAX32664D has not rebooted and the user has not changed, the calibration information is still accurate. However, it is recommended that the host retrieve the calibration vector, identify, and keep it for a user in RAM (or flash), and then reinsert it into the MAX32664D before subsequent readings. To guarantee the precision of BP measurement for the present use, the testing process is required once a month.

Measuring BPT, SpO2, and Heart Rate on Finger is described below:

Raw Data Collection Mode: The user has the option to turn on the MAX32664D to start gathering raw PPG data for hardware testing.

AGC can be disabled in algorithm mode to gather raw PPG data. In this situation, LED currents won't be changed immediately, and the BPT, SpO2, and heart rate monitoring method should be abandoned if it doesn't agree. Even though the program is operating, the PPG readings won't be impacted. You can decrease the LED currents as demonstrated if the given PPG data is overloaded. It should be noted that MAX30101 register updates must show after both the algorithm and the MAX30101 have been enabled to avoid being overridden during setup. Only the 12-byte PPG data of the MAX30101 will be reported in received samples if the output mode is set to sensor data AGC switched off.

Algorithm Mode: BPT, SpO2 and Heart-Rate Estimation- The algorithm can calculate BP, SpO2, and heart rate once SpO2 coefficients and BPT have been calibrated.

2. Secondly, ECG AD8232 [63] module used in our integrated kit. Analog output with operating voltage of 3.3 volts Light Emitting Diode (LED) indication for lead-off detection during shutdown 3.5-millimeter (mm) jack for connecting biomedical pads. For the detailed specifications and pins configuration of ECG AD8232, check out Appendix section.
3. Thirdly, DS18B20 temperature sensor is used to get body temperature. Temperature communicates over one-wire bus communication and ranges from -55C to 125C (+-0.5) when using this sensor, [64] which has an accuracy of 9 to 12 bits. We have used DS18B20 for embedded with the ECG module for the integrated kit. The circuit diagram of our integrated kit is shown in figure 4.

Moreover, our integrated kit has been made by the accumulation of dispersed sensors and integrated senor. The dispersed kit is also implemented which creates the need for integrated kit. The dispersed kit will be explained in the coming sections with its hardware aspects. The software aspects used for both kits are the same. The detail of hardware and software aspects included in our integrated kit development is discussed below:

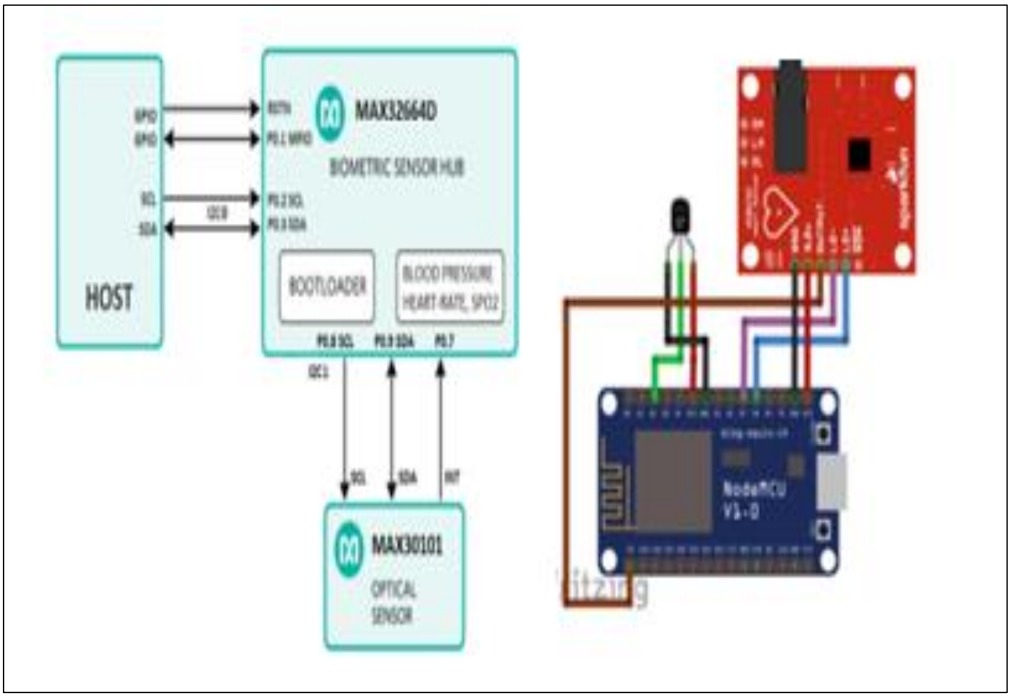

Figure 4: Integrated Kit Circuit Diagram.

3.1.1 Hardware Components of Integrated Kit

The hardware components used for the development of integrated kit are discussed in this section. The sensor details with the designed circuitry, features, specifications, pins out and its important applications are also mentioned in the respective section:

1. DS18B20

The circuit diagram of DS18B20 sensor is shown in figure 5. DS18B20 has 3 pins Ground (GND), Digital out, and Voltage Common Collector (VCC). Connections for DS18B20 sensor are mentioned below:

- GND connected to GND of Esp8266
- Data is connected to D4 of Esp8266
- VCC connected to 3V of Esp8266.

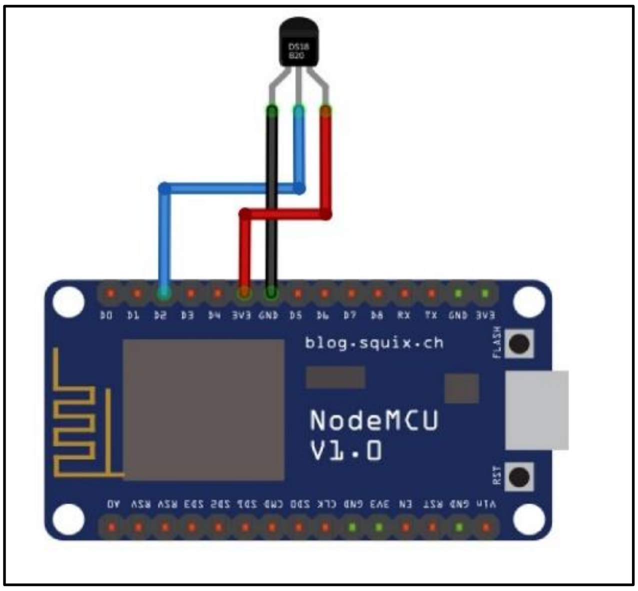

Figure 5: Circuit Diagram of DS18B20 Sensor.

Maxim Integrated Circuit (IC's) DS18B20 is the company's most extensive digital temperature sensor. Temperature ranges from -55C to 125C (+/-0.5) when using this sensor, which has an accuracy of 9 to 12 bits. Many temperature sensors may be connected to a single data bus since each has a unique 64-bit serial number programmed identifier. Many data logging and temperature control solutions depend on the proper temperature sensor. We have used DS18B20 for dispersed and integrated kit [64]. The most important features and specifications of DS18B20 are mentioned in Table 4 in appendix. Pinout and applications of DS18B20 are shown in Table 5 in appendix.

2. ECG AD8232

The circuit diagram of ECG AD8232 sensor is shown in figure 6. ECG AD8232 has a GND, 3.3V, OUTPUT, Leads Off Comparator Output (LO-) (LO+), Shutdown Control Input (SDN), Right Arm (RA), Left Arm (LA) and Right Leg (RL) Connections for ECG sensor are mentioned below:

- GND connected to GND of Esp8266
- GND connected to GND of Esp8266
- 3.3V connected to 3V of Esp8266
- OUTPUT connected to A0 of Esp8266
- LO- connected to D7 of Esp8266
- LO+ connected to D8 of Esp8266
- RA connected to Right Arm
- LA connected to Left Arm
- RL connected to Right Leg

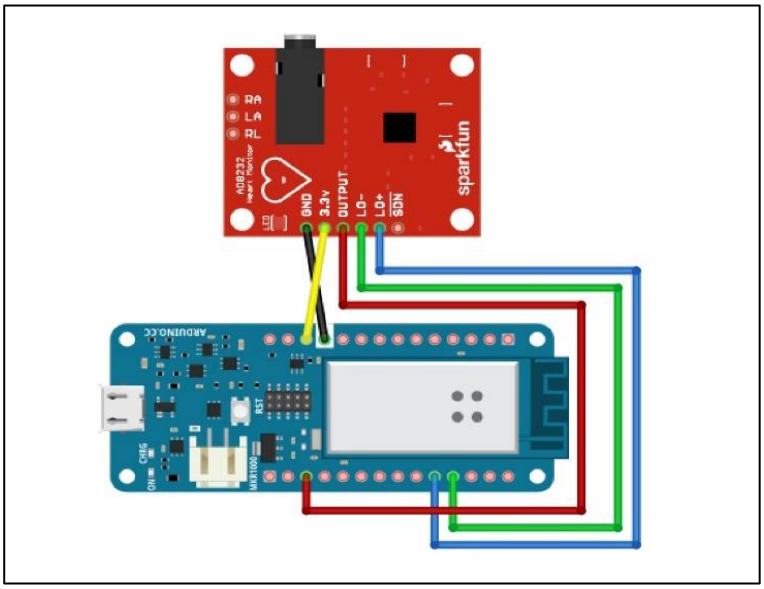

Figure 6: Circuit Diagram of AD8232.

With the single lead heart rate monitor, it's easy to keep track of your heart's electrical activity is a cost-effective solution. An ECG is a charted form of this electrical activity that provides an analogue readout. The PR and QT intervals of the ECG can be muddled by noise, and this module functions as an op amp to assist in isolating the clear signal from the noise.

ECG and other bio potential applications benefit from this signal conditioning block. Bio-potential signals can be extracted and amplified in noisy environments, such as those caused by mobility or remote electrode placement.

Analog output with operating voltage of 3.3 volts LED indication for lead-off detection during shutdown 3.5 mm jack for connecting biomedical pads. We have used AD8232 for dispersed and integrated kit [63]. ECG sensor also has various pinouts mentioned in Table 6 in appendix.

3. MAX32664D

Pulse Express has an integrated high-sensitivity optical sensor and a low-cost processor to do the computations (biometric sensor hub MAX32664D). Pulse express has an inherent algorithm that measures different data as you start, thanks to Maxim's MAX32664 version D integration. The board is excellent for finger-based wearable health applications because of its built-in low-power capabilities. The data from this board may be seen using the OpenView proto central Graphical User Interface (GUI).

Change "R" value of algorithm if SpO2 readings are unreliable or if the measured SpO2 constantly hovers at 100%. This is the case if an optical shield covers the sensor [62]. MAX32664D has a GND, Reset (RST), MFIO, Serial Clock (SCL), Serial Data (SDA) and VCC pins. The MAX32664D sensor has various essential features and pinouts mentioned in Table 7 in appendix.

4. ESP8266

Using cutting-edge low-cost Wi-Fi technology, the new node MCU V3 board offers a quick leap forward. Node MCU V3 is the most up-to-date and sophisticated LUA technology available today. It's a fully-fledged system with access to all accessible resources. It's a snap to add input/output pins to your existing Arduino projects or to any other Development Board.

Built-in USB-TTL serial with industrial-strength CH340 ensures the node MCU has the 1-wire resources you need at your fingertips, including General Purpose Input/Output (GPIO) PWM, Analog-to-Digital Converter (ADC), and I2C to provide maximum stability across all platforms. This one is among the most affordable compared to other Wi-Fi modules on the market. The most recent iteration of this module is variation 3. You may prototype your Internet of Things (IoT) device with a few lines of LUA script and open-source MCU firmware. the ESP 12 X series development kit includes GPIO, PWM, I2C, 1-WIRE, and an ADC In one place [65]. Moreover, the most essential features of ESP8266 are mentioned in Table 8 in appendix.

3.1.2 Software's Components for Integrated Kit

A combination of software and hardware components has been used to construct our proposed system. Discussion about hardware has taken place. Now, we'll talk about the software's that was utilized to create our MIoT-based cardiac healthcare system.

1. Proteus ISIS 7

PCB was the initial version of Proteus built by John Jameson, the company's chairman at the time. The most important features of Proteus are mentioned below [66]:

- Proteus has two major parts: one for circuit design and drawing and one for PCB layout design.
- First, there's Intelligent schematic input system (ISIS), a circuit-designing and simulation tool. As a second option for creating printed circuit boards, ARES can be employed.
- It also has facilities for PCB design with a three-dimensional perspective.
- Using Proteus, we can build various circuits and design multiple applications. Here we go Proteus's Introduction [66].
- Proteus is an electrical circuit design and simulation tool. The Electronic Lab Center came up with the idea.
- Proteus allows you to create two-dimensional circuits.
- This engineering program allows you to create and simulate various electrical and electronic circuits on your laptop or desktop computer.
- Preparing circuits on Proteus before making them in the real world has various advantages.

- It takes less time to design circuits on the Proteus than it does to build them in practice.
- Errors like loose connections, which might take a long time to discover in a practical circuit, are less likely to occur in software simulations.
- A significant benefit of circuit simulations is the ability to build your circuit on Proteus if some components are not feasible.
- There is no risk of any electrical component in proteus being damaged or charred in any way.
- Proteus may easily buy an oscilloscope, a relatively pricey electrical equipment.
- In an actual circuit, it's quite tricky to find circuit parents like current, voltage value of any component, or resistance at any given point.

2. **Arduino IDE**

The Arduino Software Integrated Development Environment (IDE) includes a text interface for writing code, a message box, a terminal window, a toolbar with icons/buttons for common operations, and menus. To upload and communicate with programs, it establishes a connection with the Arduino hardware [67].

3. **React Native**

As a JavaScript framework, React Native enables developers to create actual, natively rendered mobile apps for iPhone and Android. Based on Facebook's JavaScript toolkit for developing user interfaces, react is aimed toward smartphones instead of targeting browser platforms. A JavaScript framework previously familiar to web developers may now be used to create native-looking mobile apps. React Native also makes it easy to develop for Android and iPhone Operating System (iOS) simultaneously because much of the code you write can be shared between the two.

A blend of JavaScript and Extensible Markup Language (XML)-like syntax, called “JSX,” is used to develop React Native applications. The React Native “bridge” then invokes the native rendering APIs in Objective-C (for iOS) or Java (for Android). As a result, your app will appear and feel like any other mobile app since it will be rendered using native mobile User Interface (UI) components rather than web views. JavaScript interfaces for platform APIs are also exposed by React Native, allowing you to access features like the camera or location of the user [68].

4. **Firebase**

To instantly store and sync data amongst your users, you may utilize Firebase Real-time Database, a cloud hosted Not Only SQL (NoSQL) database [69]. With Cloud Fire store, you can store, sync, and query app data globally. Furthermore, firebase features are discussed below:

Easily collaborate with others using different devices:

With real-time synchronization, your users may access their data from any web-enabled or mobile device and work together more effectively.

Build serverless applications:

You don't need a server to create apps with Real-time Database's mobile and web Software Development Kit (SDKs). Cloud Functions for Firebase may also be used to run backend code that responds to events produced by your database.

Optimized for usage on the go:

Local cache on the device provides and stores modifications while users are disconnected from the network. Local data is automatically synced when the device is connected to the internet.

Strong security depending on the user's actions:

Authentication for developers is made straightforward with the Real-time Database's integration with Firebase Authentication. Using our declarative security paradigm, you may grant access based on user identification or data pattern matching.

Part of the Firebase platform:

It helps you build high-quality apps, increase your user base, and make more money as part of the Firebase platform. Each function may be used independently, but when combined, they perform much better [69].

5. **Excel Stream**

Excel streaming is used to receive and store data in tabular format. The data generated from the patient's body is helpful for an expert's predictions of any abnormality. We used the excel stream to record the ECG signals in a separate channel depending on the number of streams selected for the specific time. Our data stream for the excel sheet consists of Data in, Data out, Settings, and Manifest. The settings used for the ECG stream are a data interval of 150 ms, data rows of 2000 (1.5 minutes), 10 data channels, and the data orientation of the newest last. Once the patient's body is connected to the L, R, and F electrodes of ECG, then the data coming from the body is recorded by this streaming file. This streaming file can be used for further predictions on ECG data. The ECG data receiving setting and sample are shown in figure 7 and 8 below.

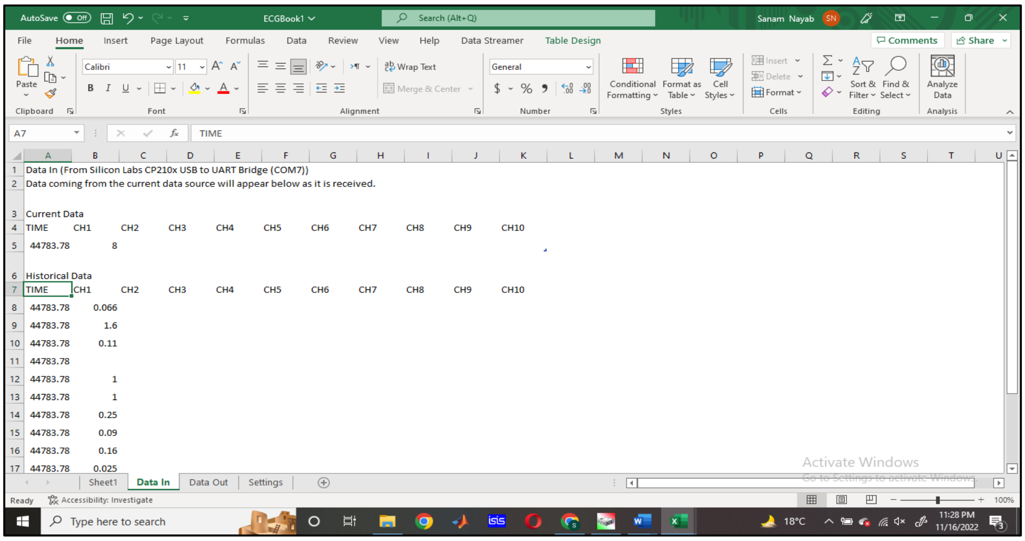

Figure 7: Excel Stream of ECG Data.

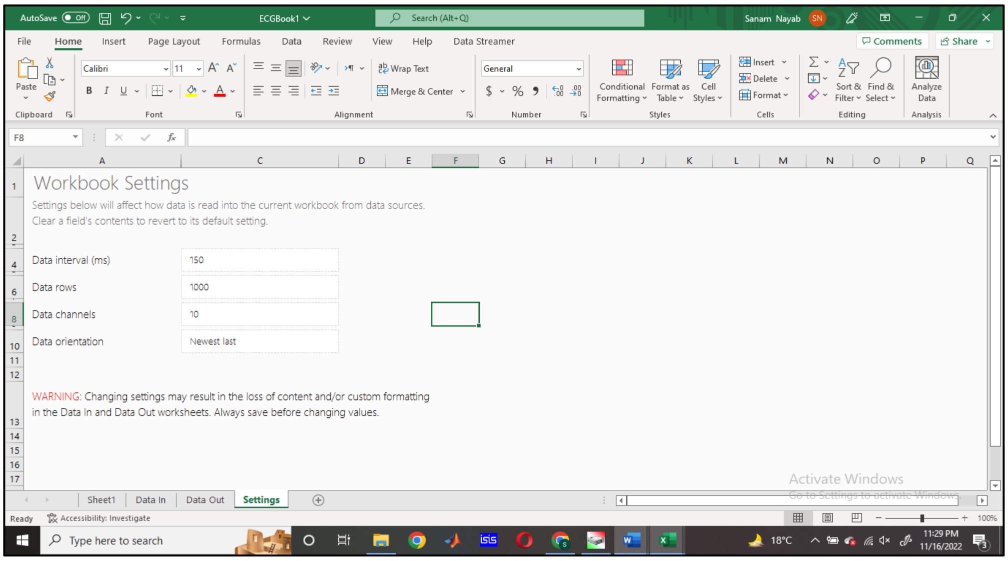

Figure 8: ECG Setting of Excel Stream.

3.2 Dispersed Kit for Cardiac System

The dispersed kit includes a variety of dispersed sensors, such as a pulse sensor, an oxygen sensor, a temperature sensor, and ECG sensor. These sensors are individually affixed to the patient's body and are used to collect sensory values from the patient. A Pulse sensor attach to the patient finger transmits heart rate data to the Arduino and then send to the Node MCU. The MAX30100 sensor also attached to the patients another finger and transmits oxygen data to the same Node MCU. The ECG AD8232 patches are affixed to the patient RA, LA, and RL and DS18B20 temperature sensor also attached to the patient finger and sent to the other Node MCU. The data from both Nodes sent to the cloud and saved in a firebase real-time database; the data from the cloud is also sent to the mobile application and kept in an excel file for future AI prediction. Figure 9 shows the circuit diagram of dispersed kit. The software components used for the complete dispersed system are the same as the integrated kit. The hardware components used for the dispersed kit development are discussed below.

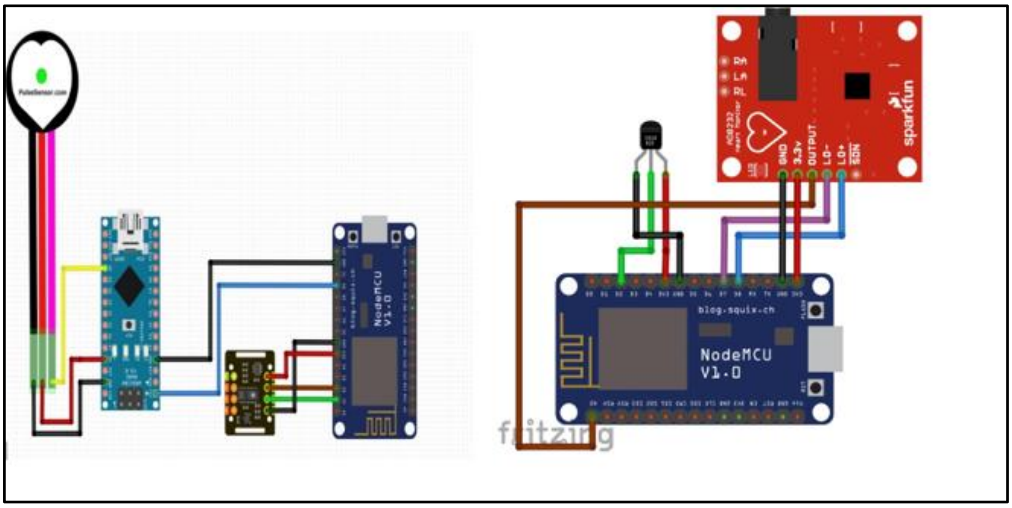

Figure 9: Dispersed Kit Development.

1. MAX30100

The circuit diagram of MAX30100 sensor is shown in figure 10. Connections for MAX30100 sensor are mentioned below:

- GND connected to the GND of Esp8266
- SDA connected to D2 of Esp8266
- SCL connected to D1 of Esp8266
- VIN connected to 3V of Esp8266.

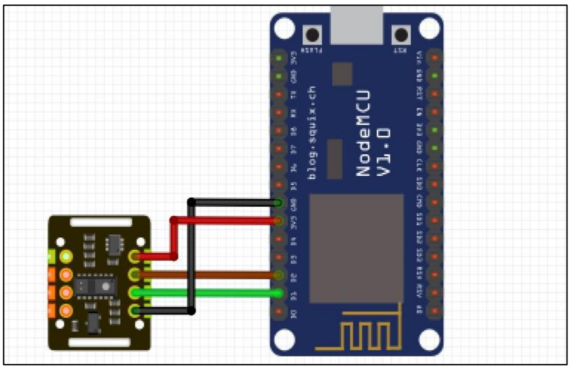

Figure 10: Circuit Diagram of MAX30100.

Pulse oximetry and heart rate monitoring are included in the MAX30100 sensor system. Pulse oximetry and heart rate signals are detected using a combination of two LEDs, a photodetector, improved optics, and low-noise analog signal processing. We have used MAX30100 to develop a dispersed IoT kit [70]. The most important features and specifications of MAX30100 are mentioned in Table 9 in appendix. And Table 10 in appendix represents the pinout and applications implemented by the MAX30100 sensor.

2. Pulse Sensor

The circuit diagram of pulse sensor is shown in figure 11. Connections for pulse sensor are mentioned below:

- GND connected to the GND of Arduino
- Signal Pin connected to A0 of Arduino
- VCC connected to 5V of Arduino.

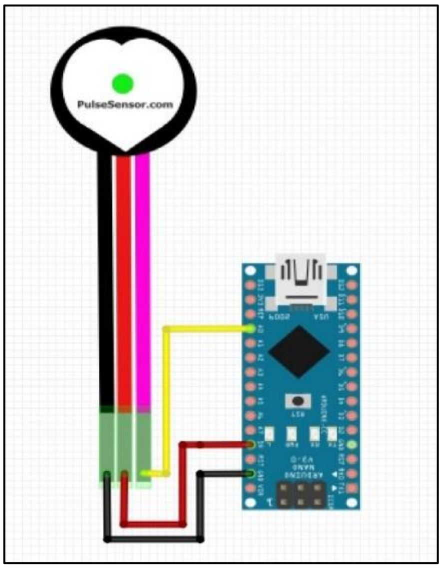

Figure 11: Circuit Diagram of Pulse Sensor.

The principle behind the pulse sensor's functioning is simple. Each end of this sensor is wired to either an LED or the circuitry; the other is connected to an ambient light sensor. This circuit aids in amplifying signals and suppressing background noise. The front of the body (ear lobes or fingertips) is where the LED is linked to a vein. It must, however, be positioned directly above the vein. The LED's beam will hit the vein dead on.

As soon as the heart begins to beat, blood will begin to circulate via the veins. Thus, by gauging blood pressure, we may assess cardiac activity. Since light is reflected by blood, ambient light sensors will pick up on lighter if blood flow is detected. Our heartbeats may potentially be detected by monitoring this minute variation in the quantity of light we receive. The volume of a blood artery changes as the heart pumps blood, resulting in a pulse wave.

A pulse sensor is a kind of detector that can measure and record this volume variation. One's pulse rate may be determined in several ways, but the electrocardiogram (ECG), photoelectric pulse wave, blood pressure measurement, and phonocardiography are the most common. Pulse sensors use a photoelectric method [71]. This is also important to understand pulse sensor features, specifications, pinout, and application. The essential features and specifications of the pulse sensor are mentioned in Table 11 in appendix. And Table 12 in appendix represents the pinout and applications implemented by the pulse sensor.

3. DS18B20

The circuit diagram of DS18B20 sensor is shown in figure 12. Connections for DS18B20 sensor are mentioned below:

- GND connected to GND of Esp8266
- Data is connected to D4 of Esp8266
- VCC connected to 3V of Esp8266.

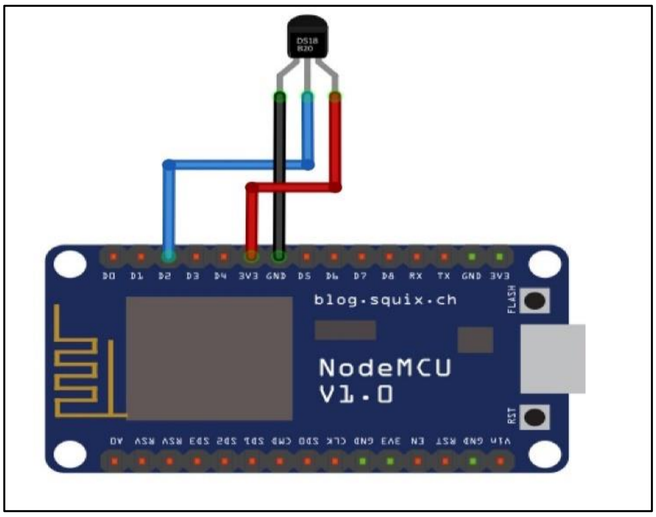

Figure 12: Circuit Diagram of DS18B20.

Maxim Integrated Circuit (IC's) DS18B20 is the company's most extensive digital temperature sensor. Temperature ranges from -55C to 125C (+/-0.5) when using this sensor, which has an accuracy of 9 to 12 bits. Many temperature sensors may be connected to a single data bus since each has a unique 64-bit serial number programmed identifier. Many data logging and temperature control solutions depend on the proper temperature sensor. We have used DS18B20 for dispersed and integrated kit [64]. The most important features and specifications of DS18B20 are mentioned in Table 13 in appendix. Pinout and applications of DS18B20 are shown in Table 14 in appendix.

4. ECG AD8232

The circuit diagram of ECG AD8232 sensor is shown in figure 13. And the connections for

AD8232 sensor are mentioned below:

- GND connected to GND of Esp8266
- GND connected to GND of Esp8266
- 3.3V connected to 3V of Esp8266
- OUTPUT connected to A0 of Esp8266
- LO- connected to D7 of Esp8266
- LO+ connected to D8 of Esp8266
- RA connected to Right Arm
- LA connected to Left Arm
- RL connected to Right Leg

With the single lead heart rate monitor, it's easy to keep track of your heart's electrical activity is a cost-effective solution. An ECG or electrocardiogram is a charted form of this electrical activity that provides an analogue readout. The PR and QT intervals of the ECG can be muddled by noise, and this module functions as an op amp to assist in isolating the clear signal from the noise.

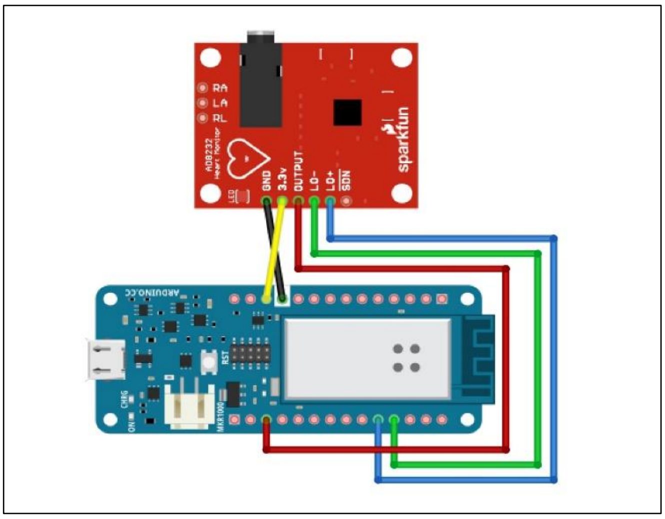

Figure 13: Circuit Diagram of AD8232.

ECG and other bio potential applications benefit from this signal conditioning block. Bio-potential signals can be extracted and amplified in noisy environments, such as those caused by mobility or remote electrode placement. Analog output with operating voltage of 3.3 volts LED indication for lead-off detection during shutdown 3.5 mm jack for connecting biomedical pads. We have used AD8232 for dispersed and integrated kit [63]. ECG AD8232 has various pinouts mentioned in Table 15 in appendix.

5. Arduino Nano

The Arduino Nano, developed in 2008 by the Italian company Arduino.cc and based on the ATmega328p, is a small, feature-rich, customizable, and breadboard-friendly microcontroller.

It has 30 male input/output (I/O) headers arranged in a DIP30 format [72]. Moreover, the most critical features of Arduino Nano are mentioned in Table 16 in appendix. And Table 17 in appendix represents the pinout and applications of Arduino Nano.

6. Vero Board

This wiring board may be used to build prototypes for bench testing, design early electronic circuits, or produce entire electronic equipment in small quantities.

The Vero Electronics Department utilized the Vero board for prototype building for the first time in 1961. Both the completed parts and the copper wires with the necessary discontinuities are visible in the photos of a binary decade counter sub-unit.

The components are typically positioned on the board's plain side, with their leads sticking out of the holes. The required connections are made with the leads by soldering them to the copper tracks on the other side of the board, and any extra wire is cut off [73].

7. ESP8266

Using cutting-edge low-cost Wi-Fi technology, the new node MCU V3 board offers a quick leap forward. Node MCU V3 is the most up-to-date and sophisticated LUA technology available today. It's a fully-fledged system with access to all accessible resources. It's a snap to add input/output pins to your existing Arduino projects or any other Development Board. Built-in USB-TTL serial with industrial-strength CH340 ensures the node MCU has the 1-wire resources you need at your fingertips, including GPIO, PWM, ADC, and I2C to provide maximum stability across all platforms. Compared to other Wi-Fi modules on the market, this one is among the most affordable. The most recent iteration of this module is variation 3. You may prototype your Internet of Things (IoT) device with a few lines of LUA script and open-source MCU firmware. The ESP 12 X series development kit includes GPIO, PWM, I2C, 1-WIRE, and an ADC In one place [65]. And the most critical features of ESP8266 are mentioned below in Table 18 in appendix.

CHAPTER 4

Testing and Results

We have discussed the outcomes of our proposed system in this chapter. Our integrated kit has undergone testing in a hospital setting. We approach the Rawalpindi clinical setting to test our integrated kit and enable real-time assessment. Objective and subjective testing informed how we set up our trial. Objective testing aims to put the objects (kits) through testing to enable assessment and comparison based on the data generated by the objects (kits). We have made objective testing and evaluation feasible by contrasting the integrated kit data to the dispersed kit values. Compared to the data produced by the integrated kit, the sensor readings from the dispersed kit differed. Second, we have used subjective assessment to make testing and evaluation practicable of our integrated kit. Subjective testing involves evaluating the integrated kit and comparing the outcomes to the data from the device used by the doctor to diagnose the subject's sickness.

4.1 Testing and Results

Our proposed system is tested in a real environment. We have analyzed the system by contrasting the outcomes of the integrated kit to the dispersed kit (objective testing). Also, the integrated kit is evaluated based on the comparison of integrated kit results and data generated from the subjects' bodies via a doctor's device (subjective testing).

In figure 14 below, we have gotten the dataset of Eight members from the real medical environment. Each patient has two rows of data: the first is from the integrated kit, and the second is from the dispersed kit for the same patient. Each column shows the corresponding value of a patient's sensory data. Figure 15 shows the ECG data streaming in an excel sheet generated by the patient in a hospital for the usage of further cardiac ailment prediction via AI technique.

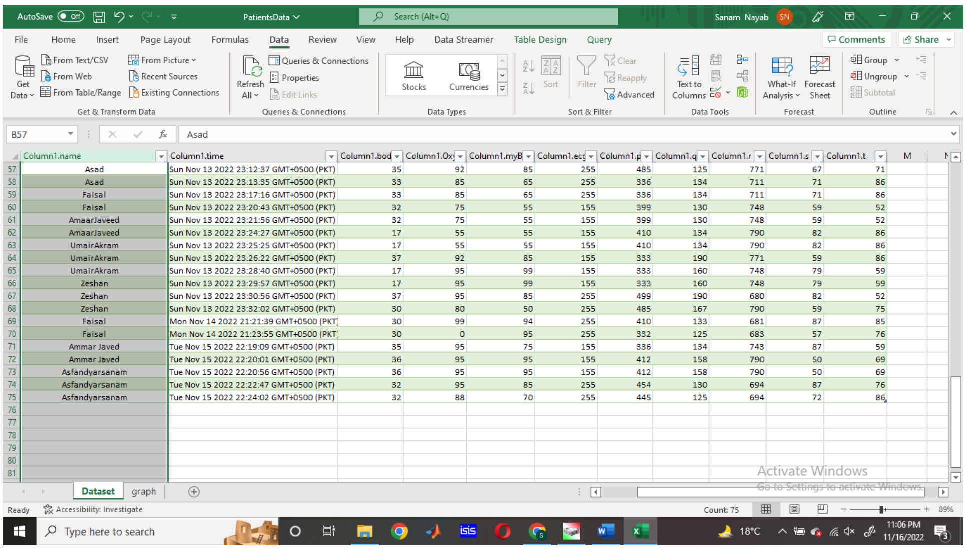

Figure 14: Patient Dataset Generated at Clinical Experiment.

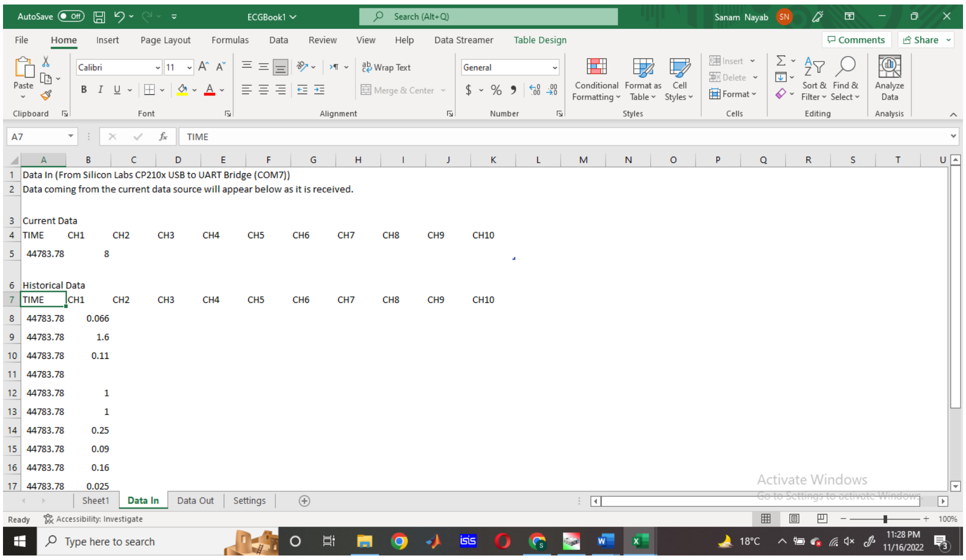

Figure 15: ECG Dataset Generated at Clinical Trails.

There are the following steps to generate the data from the dispersed and integrated kit:

1. Verify the device and connection establishments.
2. Attach the kit to the patient body.
3. Register User on mobile application.
4. Login user on mobile application by given credentials.
5. Continuous Monitoring of patient data

6. Checking Notification and alerts (if any)
7. Save Data
8. Check saved and previous patient historical data
9. Sign Out

For the step 1, we must ensure that our kit is connected to the power and Wi-Fi settings. After making sure the connections are successfully installed, we can attach the device to the patient’s body. In figures 16, and 17, we have shown the installed kits successfully in the real environment.

For the second step, after making sure the connections are established successfully, we allowed the patient to place a finger or attach the sensors to the body.

For the third step, we must register a patient before saving the data to the cloud. Click on the register button to register the patient. Provide all the necessary details such as patient name, email, contact, and password. As you can see, figure 18 shows the landing Page, and figure 19 indicates the registration page of our application.

For the fourth step, after registering the user, we must log in by providing the correct email and password. In figure 20, the login page is depicted.

For step five, now on the home page of this mobile application, doctors or family members can continuously see the patient’s health status by observing all basic and vital parametric values generated from the patient body. Figure 21 represents the receiving data from the patient via a kit.

For step six, after logging in, the family member of a patient can see the notification alerts on the application if the patient's condition is found critical. Such as, if the patient's oxygen level decreases, then the predefined threshold, the notification will continuously pop up on the application home screen. In figure 22, the pop-up notification alert on the application is shown.

For the seventh step, the data can be saved by clicking on the record sample button. The saved data will help the doctor to monitor the previous record of the patient's health condition.

For step eight, the saved data will help the doctor to monitor the last record of the patient's health condition. Figure 23 indicates the data held on the patient's health condition.

For the last step, the sign out button as shown in figure 24 is available for logging out the current patient in the application.

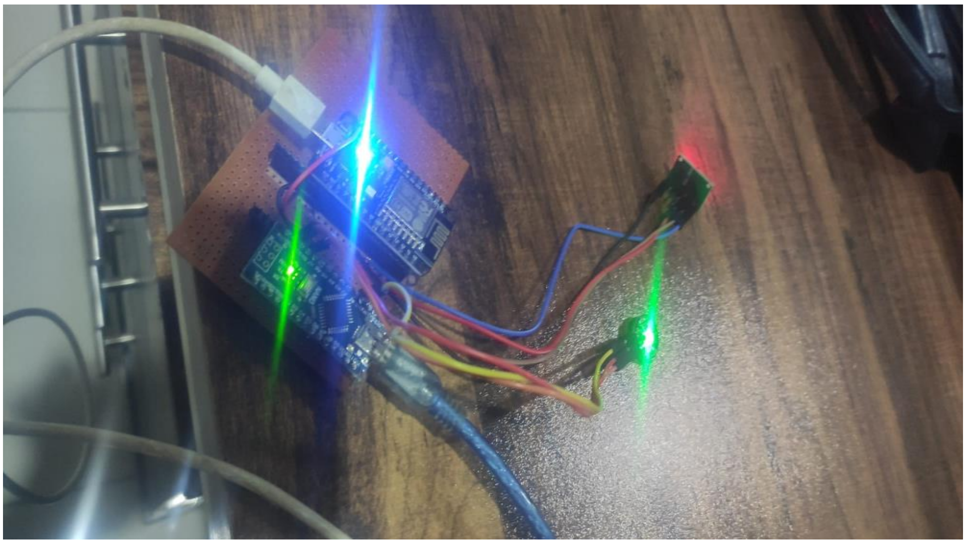

Figure 16: Installed dispersed kit successfully to the real environment.

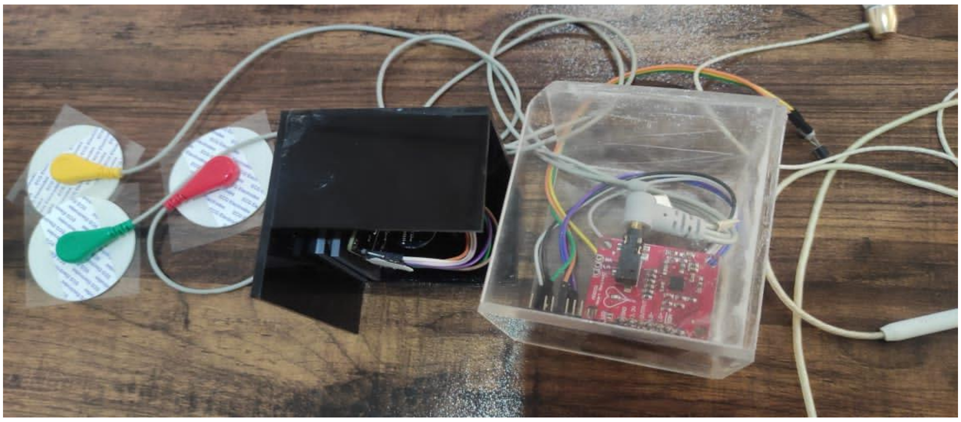

Figure 17: Installed integrated kit successfully to the real environment.

Figure 18: Landing Page of Application.

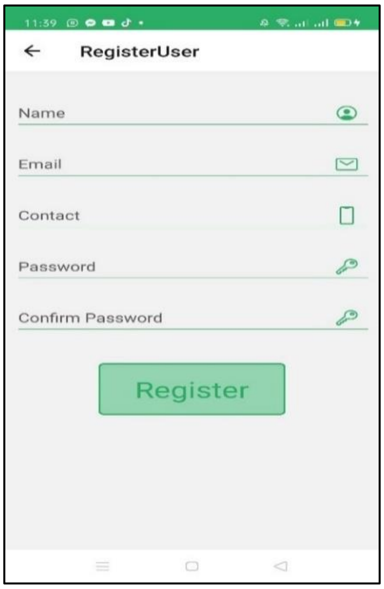

Figure 19: Registration Page of Application.

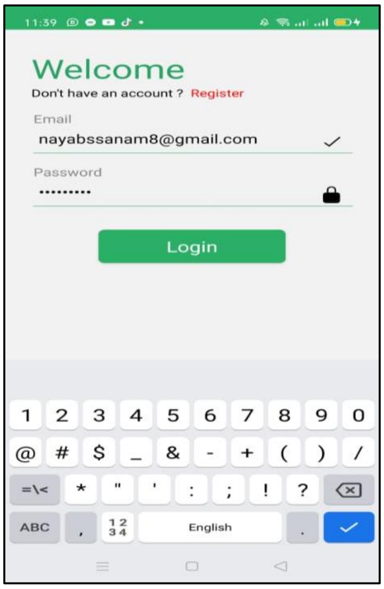

Figure 20. Login Page of Application.

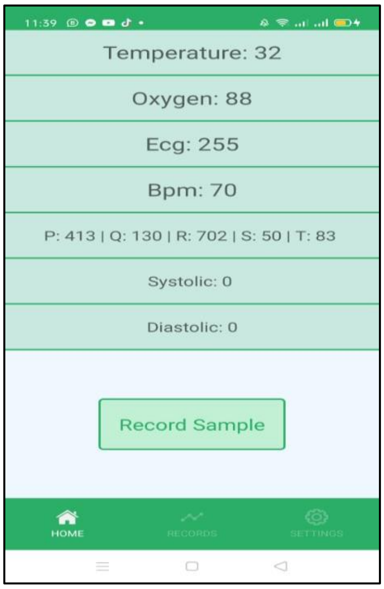

Figure 21: Home Page of Application.

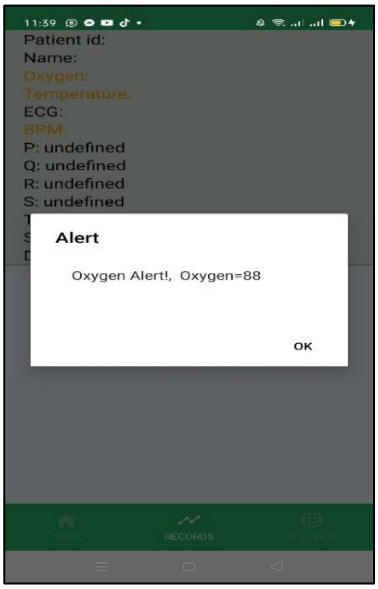

Figure 22: Alert Popup on Application.

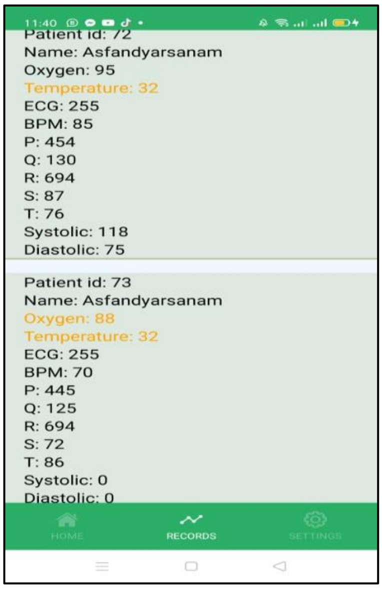

Figure 23: Saved Records/History Page of Application.

Figure 24: Saved Records/History Page of Application.

4.2 Objective Testing

There are three steps to objective testing. In the first step, the dispersed kit was tested in the actual clinical setup on patient 1. In the second step, the integrated kit is also tested on the same patient. In the third step the comparison made the evaluation results possible by analyzing the values of both objects (kits).

4.2.1 Dispersed Kit Testing

Figure 25 below shows the dispersed kit sensors held by the patient body. We have tested our dispersed kit in an actual clinical setup. In figure 26 below, the data recorded of patient 1. Consider this patient 1. We got the result of patient 1 from the dispersed kit and saved it in our real time database.

Figure 25: Testing Dispersed kit on patient 1.

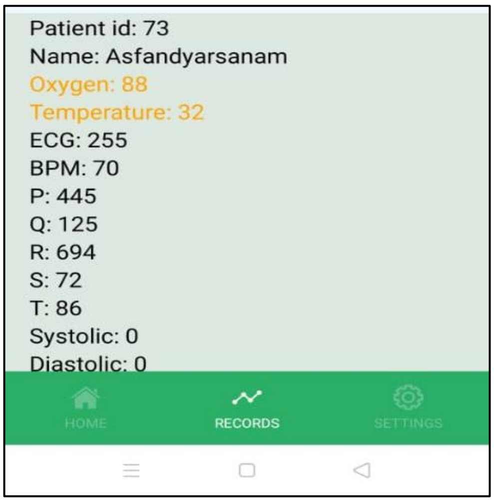

Figure 26: Data Generated from Dispersed kit from patient 1.

4.2.2 Integrated Kit Testing

Figure 27 shows the integrated kit attached to the patient's body to generate the data set. We have tested integrated on the same patient on which we tested our dispersed kit. Figure 28 below shows patient 1 data generated from the integrated kit.

Figure 27: Testing integrated kit on patient 1.

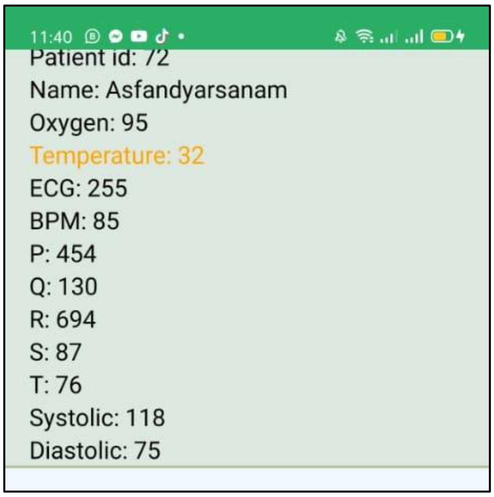

Figure 28: Data Generated from Integrated kit from patient 1.

4.2.3 Comparison Among Both Kits

We have compared the results of integrated kit to the dispersed kit based on data generated from the same patient body as shown in Table 2.

Type	Name	SpO2	BPM	SBP	DBP	Temp	ECG	P	Q	R	S	T
INT	P1	95	85	118	75	32	255	454	130	694	87	76
DIS	P1	88	70	-	-	32	255	445	125	694	72	86
DIFF	P1	7	15	-	-	0	0	9	5	0	15	10

Table 2: Comparison among both kits Data of Patient 1.

The INT type row represents the data of patient generated from the integrated kit. The DIS type row represents the data generated by the dispersed kit from the same patient body. The DIFF type of row shows the difference among the results of both kits. The integrated kit shows 95 percent oxygen value of patient, but the dispersed kit shows 88 percent oxygen value with the difference of 7 percent of the same patient which means the patient is in critical condition and needs immediate treatment. By the doctor's analysis and suggestion, the integrated kit shows the patient's oxygen value is considered normal which is correct, but the dispersed kit indicates the patient oxygen value is abnormal which is incorrect. As far as heart rate is concerned, the integrated kit shows the heart of the same patient is 85 bpm, which is correct (closer to the doctor device; mentioned in coming section). But the patient's heart rate is 70 bpm with the difference of 15, shown by the dispersed kit which is incorrect. The blood pressure sensor value on dispersed kit data is not mentioned because there was unavailability of a BP sensor in the market. ECG and temperature values are almost identical because we have used the same and available ECG and temperature monitoring sensors.

4.3 Subjective Testing

Subjective testing consists of 3 steps. In the first step, the integrated kit was tested in the actual clinical setup on patient 1. The doctor's device was used in the second step for getting the same patient's parametric values. In the third step, the comparison made the evaluation results possible by analyzing the integrated kit and doctor device values.

4.3.1 Integrated Kit Testing

Figure 29 shows the integrated kit sensors held by the patient body. We have tested our integrated kit in a real clinical setup. The integrated kit was attached to the same patient, to which the dispersed kit was already tested. In the first step of subjective testing, we tested the integrated kit on patient 1 and saved the results over the cloud, as shown in figure 30.

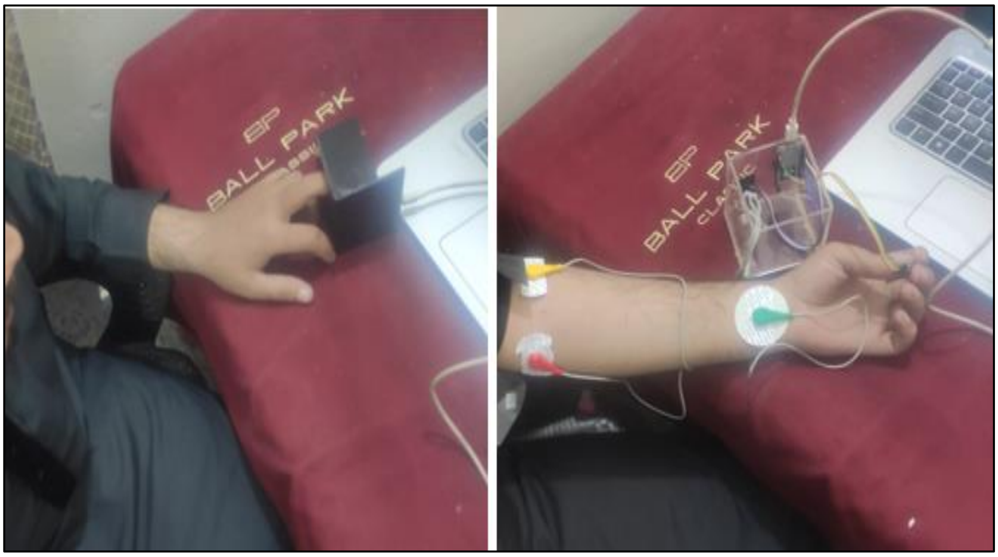

Figure 29: Testing integrated kit on patient 1.

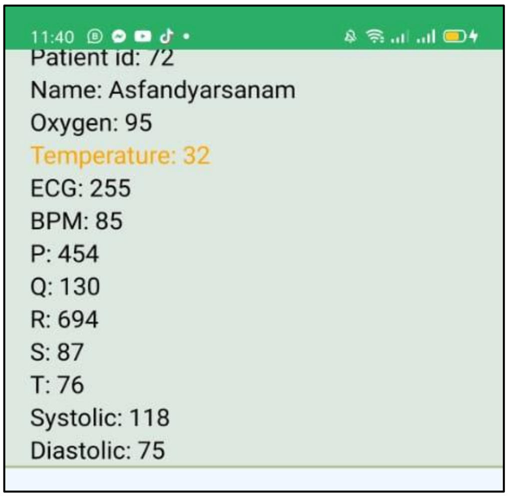

Figure 30: Data Generated from Integrated kit from patient 1.

4.3.2 Doctor Device Data

The second step of subjective testing, the doctor's device is used to generate the patient's healthcare values for the testing purpose of our proposed system. The doctor's device was tested on the same patient on which the integrated device was being tested. Figures 31, and 32 below show the results of patient healthcare values generated by the doctor device used in the actual medical setup.

Figure 31: Data Generated from Doctor Device of patient 1.

Figure 32: Data Generated from Integrated kit from patient 1.

4.3.3 Integrated Kit and Doctor Device Comparison

We have compared the results of the integrated kit and doctor device for the data generated by the same patient body as shown in Table 3.

Type	Name	SpO2	BPM	SBP	DBP	Temp	ECG	P	Q	R	S	T
INT	P1	95	85	118	75	32	255	454	130	694	87	76
DD	P1	95	89	118	73	32	255	454	125	694	72	86
DIFF	P1	0	4	0	2	0	0	0	5	0	15	10

Table 3: Comparison among Integrated kit and Doctor Device.

The type of INT row represents the data of patient generated from the integrated kit. The type of DD row represents the data generated from the doctor's device of the same patient's body. The DIFF row represents the difference between both kits results. You can see in type of INT row above; the SpO2 level of patient using integrated kit was recorded 95 percent. According to the doctor, the patient does not have oxygen level issues, that's why the 95 value of patient oxygen is correct than dispersed kit. The patient's heart rate is 85 bpm, as shown by the integrated kit row. The type of DD row, you can see the heart rate of the same patient is 89 bpm. According to the doctor's suggestion, the integrated kit generated more closer and accurate data than the dispersed kit. The type of INT row also shows the patient blood pressure values. The systolic value of a patient is 118, and the diastolic value is 75. On the other side, the doctor's device shows the systolic value is 118, which is accurate, and the diastolic value is 73. The ECG values are almost similar because the same device was used.

As per the doctor opinion and comparison among integrated and doctor device, the integrated kit is found to be more efficient, accurate, well-assembled, closer results to doctor device, and addresses more healthcare values from a single device. Thus, the expert's opinion and comparison to the doctor device proved that our integrated kit is more accurate than the dispersed kit.

4.4 Results Summary

As shown in the above sections, the testing has been done in two ways. The first way of testing is called objective testing. And the second way of testing is subjective testing. For the objective testing, we have compared the integrated and dispersed kit results for the data generated by the same patient body. By comparing the results of integrated kit and dispersed kit under observation of the doctor, the integrated kit found to be more accurate than the dispersed kit. Specifically, the dispersed kit indicated abnormal oxygen values of the same patient while the integrated kit showed correct and normal oxygen values of the same patient. The dispersed kit showed SpO2 values of the patient is 88 which means the patient needs immediate medical attention due to lower percentage of oxygen. On the other hand, the oxygen level of the same patient was monitored and tested by the integrated device which shows the patient SpO2 level is 95 which is normal. So, as per the comparison of both kits dispersed kit shows the patient oxygen level is critical but integrated kit shows the patient has a normal oxygen range. As per the doctor observation and kits results the oxygen value of integrated kit was considered correct because the patient condition was normal. As far as heart rate values comparison among both kits are concerned, the dispersed kit showed 70 bpm of the patient and the integrated kit showed 85 bpm of the same patient which was correct. The ECG values of both kits are almost the same because the same ECG device was used for both kits. The dispersed kit does not have a BP sensor because there is an unavailability of BP sensor in the market. The subjective testing allows for comparing the results of the integrated kit to the device used at the doctor's clinic for patient monitoring at real time. We have compared the results of the integrated kit and doctor device based on the data generated by the same patient body. As per the doctor's suggestions and device comparisons, the integrated kit results were closer to the doctor's device. During the subjective testing the doctor device shows the patient's heart rate is 89 bpm and our integrated kit shows the heart rate of patient is 85 bpm which is considered by the doctor a correct beats per minute value of a patient. Similarly, using our integrated kit the systolic value of the patient was recorded as 118, and the diastolic value was recorded as 75. On the other side, the doctor's device shows the systolic value is 118, which is accurate, and the diastolic value is 73. So, as per the comparison and observation of doctor the blood pressure values generated by the integrated kit has the very closer results to the doctor device. Therefore, our integration is considered the generating the correct blood pressure values also. As far as oxygen value is concerned, the SpO2 level of patients using integrated kit was recorded 95 percent. According to the doctor, the patient does not have oxygen level issues, that's why the 95 value of patient oxygen seems correct than dispersed kit. The ECG values are almost similar because the same device was used.

So, as per the expert opinion and objective and subjective type of testing the integrated kit is found to be more efficient, accurate, well-assembled, closer results to doctor device used at the real time and addresses more healthcare values from a single device. Thus, the expert's opinion proves our integrated kit is more accurate.

CHAPTER 5

Conclusion

In this chapter, we have explained the overall summary, challenges, and limitations regarding our proposed system. The summary portion included discussions of the central concept, the problem description, our contribution, the originality of our approach, aims, implementation, and testing of the suggested system. In the challenges section, we have discussed the challenges and difficulties that came across for the development, implementation, and testing of this proposed system. We've laid out the system's weaknesses in the limitations section so that future researchers will know where to look for opportunities to enhance the system.

5.1 Summary

Cardiovascular diseases (CVDs) are the world's biggest cause of mortality. In 2021, the WHO reported that CVDs caused 17.9 million deaths globally, or about 32% of all fatalities. Arrhythmia, or heart rhythm abnormalities, is the leading cause of sudden cardiac death. As of the year (2019), 7% of Pakistan's total population, or 15 million individuals, are 60 or older. As of 2050, there will be 40 million people over 60, making up about 12% of the total population. Several problems with the current cardiac healthcare system have been identified, including a lack of addressing basic and vital parameters, the dispersion of sensors, excessively long wait times especially for elderly patients, high costs, a lack of convenient locations, and the necessity for frequent physician visits. IoT is generally seen as the most practical and low-cost solution to the issue of continuous patient monitoring. If we want to improve cardiovascular health, we must adopt ubiquitous healthcare. Life-threatening cardiac patients endure long wait periods specifically for old age patients, expensive therapy, and repeated sessions to visit specialists in another city. Rural medical care shortages have made things worse. An IoT-based cardiac healthcare monitoring system incorporates IoT sensors and technology that must be linked to the patient's body to collect sensory input and transfer data to the cloud for further monitoring, processing, and decision making. IoT-based cardiac healthcare monitoring systems include heart rate, blood pressure, temperature, oxygen saturation, and ECG. Pakistan has a lack of such an IoT-based cardiac solution. Recently, cardiac monitoring systems that focus on a few parameters have received much interest. Since there is no MIoT-based cardiac healthcare system where all cardiac parameters must be monitored. Current technologies acquire patient data via dispersed sensors. This means there is no integrated MIoT-based cardiac healthcare system that can monitor patient data. Also, earlier studies were deficient in addressing all the important cardiac components of patients and failed to produce alerts if a patient's status deteriorated. No standardized protocol exists for informing caregivers of patient problems. This cardiac monitoring system's goals are: 1: To address all essential cardiac parameters. 2: To provide cardiac patients with an integrated solution. 3: Notify patient's relatives or nurse if health is abnormal. 4: Availability of such an integrated cloud based cardiac solution in our country Pakistan. We present an integrated solution for MIoT-based cardiac healthcare monitoring systems. Our new system includes: 1: Integrated solution for cardiac patients. Current cardiac care is dispersed. Basically, our integrated system reduces sensor dispersion. 2: Comprehensive cardiac solution that covers all the basic and vital parameters. Several earlier studies address few cardiac parameters. Existing research lacks an approach that addresses all the basic and vital parameters. 3: A smartphone app alerts the patient's relatives if their condition becomes abnormal. Existing cardiovascular monitoring systems lack alarms and cautions. When a patient's condition is determined abnormal, our system shows a notification on the mobile app. 4: Availability of integrated cloud based cardiac solution in Pakistan. In short, our system's proposed technique includes few steps. First, a dispersed and integrated kit was implemented to measure heart sensory values. After obtaining patient bodily data, it's sent to the cloud and mobile application. The smartphone app shows patient sensor data continuously in real time. This application lets doctors and family members remotely monitor patient health. The smartphone app informs a patient's family to take significant action for patient health. Patient data can be seen for historical view in the application. Excel streaming of data is also preserved for dataset development or deploying an AI approach for heart illness prediction in real time. Our proposed system is tested in a real environment. We have tested the integrated kit by comparing the integrated kit values to the dispersed kit (objective testing). Also, the integrated kit was also tested by comparing its results to data from a doctor's device (subjective testing). As per the comparison values and the doctor’s suggestion, the integrated kit was found to be more efficient, accurate, well-assembled, and addresses more healthcare values than the dispersed kit. The comparative results and expert's viewpoint prove our integrated system's efficiency and accuracy.

5.2 Contributions

The following are some important contributions of the performed study:

- It provides a complete solution addressing all the basic and vital cardiac parameters of cardiac patients.
- It also implements a ubiquitous healthcare system consisting of an additional feature of notification alert.
- It provides an integrated cloud-based solution for cardiac patient monitoring in our Country.

5.3 Challenges

There are few challenges faced during the implementation of this proposed system:

- Selection of integrated sensor and the unavailability of that sensor in our country.
- Selection of integrated sensor and the unavailability of that sensor in our country.
- ECG data generation from the available device was difficult for the correct real time monitoring purpose.

5.4 Limitations and Future Work

Our system can be improved in terms of the following:

- Unavailability of low-cost ECG sensor or device to get the more accurate cardiac readings.
- With the integrated solution, a more effective and smart alarm system should be implemented.

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APPENDIX A

Appendix A- Sensor Specifications and Features

The ECG AD8232 has the following pins configurations:

- HPDRIVE: High-Pass Driver Output. The capacitor in the first high-pass filter should be connected to HPDRIVE. This pin is driven by the AD8232 to maintain the same voltage level as the reference.
- +IN: Instrumentation Amplifier Positive Input. It is common for +IN to be linked to the electrode on the Left Arm (LA).
- -IN: Instrumentation Amplifier Negative Input. -IN is commonly attached to the electrode on the Right Arm (RA).
- RLDFB: Right Leg Drive Feedback Input. The right leg drive circuit's feedback terminal is identified by the letters RLDFB.
- RLD: Right Leg Drive Output. The RLD pin should be connected to the electrode that is being driven.
- SW: Fast Restore Switch Terminal. Using the second high-pass filter's output as a connection,
- OPAMP+: Operational Amplifier Noninverting Input
- REFOUT: Reference Buffer Output. This potential is used as a reference for the output of the instrumentation amplifier. Any place in the circuit where a signal reference is required can use REFOUT as a virtual ground.
- OPAMP- : Operational Amplifier Inverting Input
- OUT: Operational Amplifier Output. The output of the operational amplifier is denoted by the symbol OUT. It is at this output that you will find the properly conditioned heart rate signal. ADC input can be linked to OUT.
- LOD-: Leads Off Comparator Output. When the electrode to -IN is disconnected, LOD- is high, and when it is connected, it is low. LOD- is usually low in ac leads-off detecting mode.

- LOD+: Leads Off Comparator Output. When the +IN electrode is disconnected in dc leads-off detection mode, LOD+ is high; when connected, it is low. If either the -IN or +IN electrodes are disconnected, LOD+ is high, while it is low if both electrodes are connected.
- SDN: Shutdown Control Input. Enter low-power shutdown mode by reducing SDN's speed.
- AC/DC: Leads off Mode Control Input. Drive the AC/DC pin low to turn off the DC outputs. To turn off the ac leads, set the AC/DC pin to a high value.
- FR: Fast Restore Control Input. Fast recovery mode is activated if the FR is set to high; otherwise, it is set to low.
- GND: Grounding of the power supply
- +VS: Power supply terminal
- REFIN: Reference Buffer Input. Set the level of the reference buffer with REFIN, a high impedance input terminal.
- IAOUT: Instrumentation Amplifier Output Terminal.
- HPSENSE: High-Pass Sense Input for Instrumentation Amplifier. Connect HPSENSE to the junction of R and C that sets the corner frequency of the dc blocking circuit.
- EP: Exposed Pad. The exposed pad can either be connected to GND or left disconnected.

Sensor Name	**Features**	**Specifications**
DS18B20	Features of DS18B20 are [64]: • The unique 1-wire interface requires only one port pin for communication. • On board Read only memory (ROM), each device has a unique 64-bit serial number. • Distributed temperature sensing is made more accessible by the multi-drop capability. • Does not call for the addition of any more components. The data line serves as a power source for this device. The voltage range for the power source is 3.0 to 25.5 V. • Measures body temperature ranged from -55 degrees Celsius to +125 degrees Celsius (-67 degrees Fahrenheit to 257 degrees Fahrenheit). • -10°C to +85°C accuracy of +/- 0.5°C.	Specifications of DS18B20 are mentioned below [64]**:** • Programmable Digital Temperature Sensor • 1-Wire Method of Communication. • Operating Voltage: 3 to 5 V • Temperature Range: -55° to +125°C • Accuracy: 0.5% • It has a programmable output resolution of 9-bit to 12-bit (programmable) as well as a unique 64-bit address that may be used for multiplexing. • Available as To-92, SOP, and even as a waterproof sensor

	• The device's menu may select a temperature resolution of 9 to 12 bits. • 750 milliseconds to convert a single word of temperature into a 12-bit digital word (Max). • There are no extra components needed to do this task. • The alarm search command discovers and addresses devices whose temperature exceeds program restrictions and is user-definable Non-Volatile (NV) (temperature alarm condition) • Thermostatic controls, industrial systems, consumer goods, thermometers, and any other thermally sensitive system are examples of possible uses.	

Table 4: DS18B20 Features and Specifications.

Sensor Name	**Pinout**	**Applications**
DS18B20	DS18B20 pin outs are [64]: • GND: Connected to the ground of the circuit. • VCC: 3.3V or 5V • Data: The pins give output the temperature value, which can be read 1-wire method.	DS18B20 used for [64]: • Thermostatic controls • Industrial systems • Consumer items • Thermometers • Thermal intransitive systems • Thermometers

Table 5: DS18B20 Pinout and Applications

Sensor Name	**Pinout**
ECG AD8232	AD8232 has the following pinouts [63]: • GND: Power Supply Ground • 3.3V: Power Supply 3.3V

	• Output (ADC): Operational Amplifier Output. It is at this output that you will find the properly conditioned heart rate signal. ADC input can be linked to OUT. • LO-: Leads from Comparator's Output to "LO-" When the electrode to IN is removed, LO is high; when connected, it is low in the dc leads off detection mode. • LO+: The output of the Comparator is LO+. Disconnecting the Instrumentation Amplifier Positive Input (+IN) electrode raises LOD+ in dc and leads off detection mode, whereas connecting lowers LOD+. • SDN: System Shutdown Activation may be put into low-power shutdown mode by lowering its voltage. • RA: RED Biomedical electrode pad RA (input). Amplifier with Negative Input. The electrode on the RA is commonly used as the IN connection. • LA: YELLOW Biomedical electrode pad LA (input). Positive Input to an Instrumentation Amplifier. The electrode on the LA is usually attached to the +IN line. • RL: GREEN Biomedical electrode pad RL (input). Leg Drive Output on the Right. The RLD pin should be connected to the electrode that is being driven.

Table 6: ECG Pinout.

Sensor Name	Features	Pinout
MAX32664D	Features of the integrated sensor are [62]: • A high-sensitivity pulse oximeter and heart rate sensor are integrated into one device (Integrated). • Biometric sensors hub that is fully integrated • To identify and correct motion artifacts with a built-in accelerometer. • Any host microcontroller may be connected using the simple I2C interface.	This integrated sensor has a pinout [62]: • GND: Ground of the Power Supply • RST: External System Reset (Active Low) input. • MFIO: Multifunction Input/Output to connect with the sensor hub, the host asserts MFIO low (MFIO works as an input; MFIO is kept low after a reset, the sensor hub enters bootloader mode). • SCL: I2C serial clock.

	• The use of extremely low power (ultra-low power) • Pulse blood oxygen saturation (SpO2) • Calculated blood pressure. • 35 mm x 17 mm dimensions	• SDA: I2C serial data • VCC: 3.3V Supply Voltage

Table 7: MAX32664D Features and Pinout.

Component	Features
ESP8266	Features of Node MCU is as follows: • Wireless 802.11 standard • Wi-Fi at 2:00 0.4 GHz, support Wi-Fi Protected Access (WPA/WPA 2) security mode. • Built-in Transmission Control Protocol/Internet Protocol (TCP IP) protocol stack to support multiple TCP client connections. • Support UART/GPIO data communications • Remote firmware upgrade • Support smart links for wireless networking. • Don't need to download resetting. • Great software for developing Node MCU applications. • Lowest cost Wi-Fi • For Arduino like hardware, I/O • Open source, interactive, programmable, low cost, simple, smart Wi-Fi enabled. • Event-driven API for network applications facilitates developer writing code running on a 5 mm * 5 mm seized MCU in Node JavaScript style.

Table 8: ESP8266 Features

Pins

Esp8266 has 17 GPIO (General Purpose Input Output) pins and only 11 of the pins are best to use. The following lists of 11 pins are:

- D0-D8
- Tx
- Rx
- Ao

Power Pins

VIN: The esp8266 board may be powered by connecting this pin to Vin. It may be powered by as much as 5 volts. If you have a regulated 5V supply, you may directly power the Node

MCU esp8266 and its peripherals from the Vin pin. The esp12e chip requires 3.3 volts. Thus the 5 volts it receives are reduced by a voltage regulator to 3.3 volts.

Note: It's worth noting that the Lolin ESP8266 module includes one more pin, VU. For external devices, you can obtain 5V from the VU pin if the module's USB power is 5V.

3.3V: The 3.3V pins are available on the PCB. External components can be powered using the 3.3V pin, which is the output of a voltage regulator (CP2102).

GND: There are a total of four GND pins on the board.

Note: Not all ESP8266 I/O pins are tolerant of 5V; therefore, keep that in mind when using the ESP8266 in your projects. The board can be damaged if it receives more than 5 volts of power from any pins.

ADC: When using the ESP8266's built-in 10-bit ADC or analog-to-digital converter, the ESP8266 has just one analog to digital converter. For example, sensors and potentiometers connected to the board's single analog pin can be read in analog voltage. The board's A0 analog pin is shown in the pinout diagram above.

UART Pins: The Universal Asynchronous Receiver and Transmitter Pins:

One UART interface is UART0, which is used by RX0 and TX0 on the esp8266 board, whereas UART1 is used by RX2 and TX2. The firmware or software is uploaded using the UART1.

UART0 Pins:

- U0 TxD (GPIO1)
- U0 RxD (GPIO3)

UART1 Pins:

- U1 TxD (GPIO15)
- U1 RxD (GPIO13)

SPI Pins: The Esp8266 NodeMCU has only one set of SPI pins, unlike the three UART interfaces. Master Output/Slave Input (MOSI), Master Output/Slave Input (MISO), Clock Line for the Clock Signal (SCLK), and Chip Select (CS) are required for the SPI protocol.

- GPIO 7: MISO
- GPIO 8: MISO
- GPIO 6: SCLK
- GPIO 11: CS

I2C Pins: The ESP8266 does not have any hardware pins for I2C communication, although it is possible to program it in. So, as long as you're familiar with I2C programming, you can utilize any GPIO pin as an I2C. To use I2C, you only need two pins: SDA and SCLK.

Usually, the following GPIOs are used as I2C pins:

- GPIO 4: SDA
- GPIO 5: SCL

PWM Pins: The board has four PWM-enabled pins. Digital motors and LEDs may be driven via the PWM output. Pins GPIO 4 through 15 on the ESP8266 board are used for PWM. OR the digital pins D2, D5, D6, and D8.

Appendix A

EN or Enable Pin: ESP12E's esp8266 chip may be turned on by pulling the EN (Enable) pin to its high position. Pulling down the EN pin drastically reduces the chip's power consumption.

RST: This pin resets the board when pushed low. An inbuilt reset button is akin to this.

Wake Pin (D0): This pin brings up the ESP8266 from a long slumber.

NOTE: EN, RST, and Wake pin are called the control pins of the ESP8266 board.